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THE DEVELOPMENT OF FISHERY COMPARTMENTS AND POPULATION RATE COE--ETC(U)
JUN 77 G R LEIDY, R M JENKINS

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The results of analyses designed to develop model fishery compartments and associated fish population rate coefficients on a regional basis for use in reservoir ecosystem modeling are presented. Emphasis is directed toward development of regional rate coefficients for the United States corresponding to major geographical drainage areas. Fishery data will be incorporated in the reservoir ecosystem model currently being developed by personnel of the Environmental Effects Laboratory, U. S. Army Engineer Waterways Experiment Station. next page

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Known physical, chemical, and fishery conditions in 187 Corps of Engineers (CE) impoundments larger than 500 acres are described. Multivariable equations are presented that allow estimation of standing crop and sport fish harvest in CE reservoirs.

The development of fishery compartments and population rate coefficients is described. Five fish compartments and their corresponding food compartments were developed to describe the feeding of reservoir fish populations. The fish compartments are piscivores, planktivores, benthos feeders, detritivores, and fish that feed on terrestrial food sources. The five food compartments corresponding to these fish compartments are, respectively, prey fishes, zooplankton, benthos, organic, detritus, and terrestrial organisms. Fish biomass is proportioned among these compartments on a regional basis.

The relations among fishery compartments and to other fish population parameters were investigated. Where applicable, regional rate coefficients were developed for fish production, reproduction, recruitment, growth, mortality, and sport and commercial harvest.

Data were also reviewed and summarized on the ecological growth and assimilation efficiencies of fish, food consumption rates, respiration rates, temperature tolerances, half-saturation constants for growth, and chemical composition. Text and appendices detail the results of these various studies.

PREFACE

The work described in this report was performed under cooperative agreement No. WES-76-2, between the U. S. Army Engineer Waterways Experiment Station (WES), Environmental Effects Laboratory (EEL), Vicksburg, Mississippi, and the U. S. Department of the Interior, Fish and Wildlife Service, National Reservoir Research Program (NRRP), Fayetteville, Arkansas, signed 3 November 1975. The research was funded through the Civil Works Environmental Impact Research Program, Office, Chief of Engineers (OCE).

The research was conducted and the report written by Mr. G. R. Leidy and Mr. R. M. Jenkins of the NRRP. The efforts of Mrs. J. A. Bilbrey for typing and proofing the text, tables, figures, and appendices of this report are acknowledged.

Dr. K. W. Thornton, Ecosystem Research and Simulation Division (ERSD), EEL, was the Contract Monitor and was responsible for the performance of the agreement. The study was under the supervision of Mr. D. L. Robey, Chief, Ecosystem Modeling Branch, ERSD, and Dr. R. L. Eley, Chief, ERSD, and the general supervision of Dr. J. Harrison, Chief, EEL. The OCE Technical Monitor was Mr. John Bushman.

Commanders and Directors of WES during the study and preparation of this report were COL G. H. Hilt, CE, and COL J. L. Cannon, CE. Technical Director was Mr. F. R. Brown.

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CONVERSION FACTORS, U.S. TO METRIC (SI) UNITS OF MEASUREMENT

U.S. customary units of measurement used in this paper can be converted to metric (SI) units as follows:

Multiply	By	To Obtain
inches	25.4	millimeters
feet	0.3048	meters
miles	1.609344	kilometers
square miles	2.58999	square kilometers
acres	0.40468	hectares
acres	0.0040468	square kilometers
acre-feet	1.234	megalitres*
pounds	453.5923	grams
pounds per acre	1.120851	kilograms per hectare

* 1 megalitre = 10^6 litres = 1000 cubic meters.

THE DEVELOPMENT OF FISHERY COMPARTMENTS AND POPULATION RATE COEFFICIENTS FOR USE IN RESERVOIR ECOSYSTEM MODELING

PART I: INTRODUCTION

1. In 1973, personnel at the Environmental Effects Laboratory (EEL), of the U. S. Army Engineer Waterways Experiment Station (WES), at Vicksburg, Mississippi, began to assess and improve a comprehensive mathematical river basin model. One component of the river basin model is the reservoir system model. This model, when complete, will integrate information on the physical, chemical, and biological relationships of reservoirs. The model will allow theoretical aspects of reservoir dynamics to be tested and evaluated, as well as the impacts of proposed reservoir management plans.

2. Because reservoirs are complex systems continually in a state of flux, they are difficult to model. One approach toward simplifying this complexity, and the approach used in the reservoir model, is to divide the system into smaller, more manageable subsystems. Each subsystem can then be studied and, once understood, related to other subsystems. In this manner, the entire reservoir system can be reconstructed from component parts. This paper presents the data base for one of the reservoir subsystems--fish.

3. The purpose of this report is to provide the data base necessary for the development of a fishery model that will simulate

fish population dynamics in various types of Corps of Engineers (CE) reservoirs on a regional basis. The CE reservoirs have been classified as either hydropower or nonhydropower. Nonhydropower reservoirs do not have hydroelectric generation and are used for flood control, irrigation, water supply, recreation, and other purposes.

4. Major U.S. drainage areas (Figure 1) for which regional fishery data were developed are:

New England (including Great Lakes and St. Lawrence)
Middle Atlantic
Gulf and South Atlantic
Ohio Basin (including the Tennessee Valley)
Upper Mississippi Basin (including Souris and Red)
Lower Mississippi
Rio Grande and Gulf
Arkansas-White-Red
Missouri Basin
Columbia Basin
North Pacific
Central Valley
Central and South Pacific

No information was available to develop regional fishery data for the Colorado Basin or the Great Basin.

5. The remainder of the report consists of two parts. The first part describes the chemical and physical characteristics of all CE reservoirs in the United States larger than 500 acres* in area. Where available, information on fish species present and the sport and commercial harvest is also provided. Mathematical formulas are presented that allow the prediction of fish standing crop and sport fish harvest in CE reservoirs. The second part describes the data base to be used

*For conversion to the metric system, see page 7.

Figure 1. Major drainage areas of the United States (from U.S. Water Resources Development Map, U.S. Geological Survey, 1963).

in developing the reservoir fishery model on a regional basis.

Presented are:

1) Fish and fish food compartment descriptions
2) Fish carrying capacity and production
3) Fish reproduction, recruitment, and harvest
4) Fish growth and mortality rates
5) Fish digestive efficiencies and half-saturation constants
6) Fish respiration rates
7) Fish temperature tolerances
8) Fish chemical composition

PART II: DESCRIPTIVE DATA FOR CE RESERVOIRS

Physical and Chemical Descriptions of Reservoirs

6. Physical and chemical characteristics of 187 CE reservoirs are presented in Appendix A. Only reservoirs larger than 500 surface acres at normal pool were included (see Appendix A for definitions of terms). Most run-of-the-river (storage ratio <0.01) navigation impoundments were excluded. All reservoirs were grouped by major drainage areas. Table 1 summarizes the numerical and areal distributions of CE reservoirs by drainage area. Reservoirs included in this study total 3,510,000 acres, or 36 percent of the total reservoir area (reservoirs larger than 500 acres) in the U.S. (National Reservoir Research Program 1976*).

Fishery Description of CE Reservoirs

7. One purpose of this study was to develop fishery statistics on a regional basis. However, it was first necessary to test the assumption that regionalization by major drainage areas would show sufficient differences in fish species composition and standing crop to warrant regional treatment. It was assumed that all reservoirs within a drainage area would have similar fish species present and that the species composition of reservoirs in one drainage area would vary to some extent from those in other drainage areas.

8. A list of fish species present was compiled for 61 CE

* All references cited in the text and appendices are listed alphabetically by author in Appendix N.

Table 1

Numerical and Areal Distributions of CE Impoundments by Drainage Area

Drainage Area	Number of Reservoirs	Total Surface Area, acres
New England	2	1,610
Middle Atlantic	7	68,947
Gulf and South Atlantic	12	308,050
Ohio Basin	49	328,484
Upper Mississippi	14	356,247
Lower Mississippi	5	78,510
Arkansas-Red-White	40	782,118
Rio Grande and Gulf	16	241,609
Missouri Basin	18	1,164,201
North Pacific	1	1,135
Columbia Basin	16	162,105
Central and South Pacific	2	2,380
Central Valley	5	14,550

reservoirs where data were available. Species composition data were not available for reservoirs in the following drainage areas:

New England
Upper Mississippi Basin
Columbia Basin
North Pacific
Central Valley
Central and South Pacific

Data were available on only one reservoir each in the Middle Atlantic, Rio Grande and Gulf, and Missouri Basin drainage areas. The reservoir sample thus includes primarily eastern and southern impoundments.

9. A cluster analysis computer program (University of Arkansas Computing Center) was used to compare the species composition of each reservoir with all other reservoirs and to group reservoirs with similar species together. The comparison was based on the presence or absence of 125 fish species. The results showed, with exceptions, that the species composition of the fish in reservoirs within drainage areas were similar. Furthermore, they showed that some drainage areas contained fish species not found in other areas. For example, yellow perch were found only in reservoirs of the Middle Atlantic and the Gulf and South Atlantic drainages. Freshwater drum were not found in reservoirs of these drainages, but occurred in all others. Lack of fish species information for all of the western drainage areas prevented testing the regional approach to modeling for those areas. Many western reservoirs with salmonids, especially cold-water reservoirs, would be expected to be markedly dissimilar to eastern and southern reservoirs.

10. Differences among drainage areas in species composition are most pronounced when examined on a species presence or absence basis. However, for modeling purposes, various fish species were grouped together on the basis of feeding similarities. At this level, regional differences in species composition were less obvious. Appendix B summarizes, by drainage area, fish species composition and standing crop data for 61 CE reservoirs. Only predominant fish species or groups of closely related species were tabulated. As expected, considerable variation exists among reservoirs in standing crop of fish. Standing crop is defined as the amount, in pounds per acre, of fish biomass present at the time measurements were made. If all of the reservoirs were compared solely on the basis of presence or absence of the major fish groups, such as suckers, black basses, or sunfishes, little variation would be apparent. On this basis, only the Middle Atlantic and the Gulf and South Atlantic drainages differed from other drainages in the absence of freshwater drum. At this level of examination, there was not much support for regionalizing reservoirs by drainage areas because the fine distinctions in fish species composition among different areas had been masked.

11. Within drainage areas most reservoirs had similar fish species and total standing crops, although the standing crops of individual species or species groups varied widely. There were notable exceptions to this generalization. Within the Ohio Basin, two reservoirs, John W. Flannagan and Summersville, had total standing crops well below those

of other reservoirs in the basin. These two reservoirs also had fewer fish species than most other impoundments. Likewise, in the Lower Mississippi drainage area, Wappapello had a much greater standing crop than other reservoirs. Species composition was also different. In the Arkansas River Basin, standing crop was extremely variable among reservoirs, and several reservoirs were appreciably different from the norm.

12. Variation was to be expected in the biological characteristics of reservoirs within a drainage area. Changes in environmental variables over the large geographical area encompassed by each drainage area influence reservoir fish populations. Furthermore, year-to-year changes occur in the fish populations of each reservoir in response to changing environmental conditions. The difficulty in accurately describing reservoir fisheries results from the use of static descriptors in analyzing a dynamic system. Finally, the data base upon which conclusions were drawn may be inadequate, as demonstrated for many drainage areas where little or no data are available. Single point measurements of a biological system like many of the fish population measurements used in this study should be viewed with caution.

13. Most of the drainage areas examined had one or more reservoirs with characteristics significantly different from those of most of the impoundments. It was difficult, therefore, to make firm statements on the fishery of reservoirs within a given drainage. In this study, reservoirs showing major differences from the norm were treated

separately when it was felt that the effect of their influence on an analysis would bias the results and conclusions.

Field Estimates of Fish Standing Crop

14. Estimates of fish standing crop used in this study were derived by sampling reservoir coves with rotenone, a fish toxicant that has been used in the United States for fishery management purposes since 1934. Cove sampling involves selecting coves that usually represent a variety of fish habitats and range from 1 to 5 acres in size. Escape of fish from the cove is prevented by using block nets at the end opening to the reservoir proper. Cove area and depth are accurately measured and a rotenone dosage is calculated on the basis of water volume and water temperature. Finally, rotenone is applied throughout the cove and all fish appearing at the surface are collected. Fish are normally collected for two days after treatment. To estimate the percentage of fish actually present that are recovered, workers place marked fish in the cove before it is treated. In some studies, scuba divers collect fish that do not float to the surface. All fish collected are sorted by species and length classes and weighed. Standing crop, usually expressed as pounds of fish per acre, is calculated from the collected data. Most cove sampling schemes involve sampling three coves of nearly similar area so that variability in samples can be estimated and a mean standing crop value determined. Cove rotenone sampling is normally performed in the summer, usually in August.

15. Even carefully planned and executed cove rotenone samples usually underestimate or overestimate the standing crop of some species for two primary reasons. First, some species of fish are not recovered adequately because they do not float to the surface where they can be collected. Fish underestimated in this manner are primarily benthic species such as catfishes, carp, suckers, and freshwater drum. Small fish of various species are also underestimated usually because they are overlooked in pickup operations. This is especially true for small shad, sunfishes, and minnows. Second, some species of fish are more abundant in the coves than in the open water of the reservoir. Cove samples overestimate the abundance of these species in the reservoir. Gars, bowfin, various sunfishes, perches, and pickerels are normally more abundant in coves than in open water. Likewise, other species which are more abundant in open water than in coves, are underestimated; such species are various suckers, temperate basses, and freshwater drum.

16. Adjustments must then be made for nonrecovery of species and for cove to open-water habitat. Adjustment factors for the previous sources of error have been estimated for a number of southern reservoirs (Hayne et al. 1967; Jenkins and Morais 1977) and are presented in Table 2. By applying the adjustment factors to the initial standing crop estimates, an adjusted standing crop value can be obtained. All standing crop estimates used in this report have been adjusted, with

Table 2

Adjustment Factors Used in Estimating Standing Crop from Cove Rotenone Samples

Species or Species Group	Adjustment for fish not recovered in cove rotenone sampling	Adjustment from cove sample to open water	Adjustment from un-adjusted standing crop to adjusted standing crop	Adjustment from un-adjusted standing crop to carrying capacity
Gars	1.44	0.8	1.15	0.81
Bowfin	1.80	0.8	1.44	1.01
Shad	1.25	1.0	1.25	0.88
Pickerels	1.37	0.8	1.10	0.77
Carp	1.40	1.2	1.68	1.18
Minnows and Silversides	1.50	0.8	1.20	0.84
Catostomids	1.34	2.3	3.08	2.17
Catfishes	1.47	1.0	1.47	1.04
Temperate basses	1.18	2.0	2.36	1.66
Sunfishes	1.46	0.6	0.88	0.62
Black basses	1.40	1.1	1.54	1.08
Crappies	1.39	1.5	2.09	1.47
Perches	1.52	0.8	1.22	0.86
Freshwater drum	1.40	2.4	3.36	2.37
All other species	1.40	0.8	1.12	0.79

the exception of estimates derived by multiple regression analysis.

Field Estimates of Fish Harvest

17. Jenkins and Morais (1971) examined in detail the relation of sport fishing effort and fish harvest to environmental variables. Their results, based on the analysis of 103 reservoirs throughout the U.S., showed that the average annual harvest of all reservoirs combined on an area-weighted basis was 14.6 pounds per acre. Area-weighted harvest values were used because Jenkins (1967) found that sport fish harvest was negatively related to reservoir area. A previous study by Jenkins (1967) showed the average annual area-weighted sport fish harvest for 127 U.S. reservoirs to be 13.9 pounds per acre. An average of 7.0 pounds per acre of commercial fish was harvested from 45 reservoirs. Sport fish harvest for individual reservoirs ranged from less than 1 to as many as 169 pounds per acre. Commercial fish harvest ranged from less than 1 to as many as 55 pounds per acre.

18. Current sport fish harvest estimates are based on a resurvey of all harvest data available in the files of the National Reservoir Research Program (NRRP). Data as recent as 1975 and representing 164 reservoirs throughout the country are summarized in Appendix C. Commercial fish harvest was not reanalyzed, but only rearranged to a form more useful for modeling. Appendix C, Part II, lists sport fish harvest by major drainage areas of the U. S. Within each drainage area, data are given on the number of reservoirs in the sample, total

reservoir area, simple and area-weighted sport fish harvest, and area-weighted harvest by species groups. Under each species group, the annual harvest is shown in pounds per acre and as a percentage of the total harvest. Only reservoirs with data on the harvest of individual fish species were included in the analysis. Harvests of less than 0.05 pound per acre were excluded. About 23 percent of the total reservoir area in the U. S. is represented in the analysis.

19. Sport fish harvest varied considerably among drainage areas, both in total harvest and in species composition. Some of this variability can be attributed to an inadequate number of reservoirs sampled within each drainage area and to a limited number of harvest estimates per reservoir. The area-weighted sport fish harvest for all reservoirs combined was 12.1 pounds per acre, as compared with a previous estimate by Jenkins and Morais (1971) of 14.6 pounds per acre. Harvest data on 48 CE reservoirs subsampled from the data set showed an unweighted average harvest of 22.6 pounds per acre and an area-weighted harvest of 13.6 pounds per acre.

20. Data on the harvest of commercial fish species were not as readily available as those for sport fish. The information compiled by Jenkins (1967) has been used in this analysis (Appendix C, Part III). Many drainage areas lacked reservoirs supporting commercial fisheries. For drainage areas with four or more reservoirs with commercial fisheries, excluding the Tennessee Valley, commercial fish harvest was low, ranging from 1.0 to 4.2 pounds per acre (area-weighted mean). The Tennessee

Valley reservoirs supported a high commercial harvest of 14.6 pounds per acre. Buffalofishes made up 65 percent of the commercially harvested species, catfish 25 percent, and carp 10 percent. The commercial fishing statistics were from reservoirs representing about 16 percent of the total reservoir area of the U. S. (three percent of the total number of reservoirs).

21. Reservoir age has a significant effect on harvest estimates. Many reservoirs become less productive of sport fish with age (Ellis 1937). Because most of the harvest estimates used in this analysis were collected when the reservoirs were relatively new, the average harvest values given may overestimate current conditions for some drainage areas, such as the White River Basin and the Rio Grande and Gulf drainage reservoirs.

Predicted Standing Crop and Sport Fish Harvest for CE Reservoirs

22. Since 1963, biologists of the NRRP have compiled and analyzed available pertinent information on the biological, physical, and chemical characteristics of U.S. reservoirs. A primary purpose of NRRP is to describe and correlate differences in fish production in terms of standing crop as estimated by cove rotenone samples and by sport and commercial fish yields with such variables as climate, reservoir size, age, uses, shore development, water depth, water level fluctuation, water chemistry, storage ratio, outlet depth, thermocline depth, dissolved organic matter, plankton and benthic fauna crops, and

other biological characteristics.

23. This research program has resulted in the development of a series of multiple regression formulas for use in predicting fish standing crop and angler harvest and effort in U.S. reservoirs (NRRP 1974). Selected multiple regression formulas from this series were used in the present study to estimate standing crop and sport fish harvest for CE reservoirs for which a fishery data base was available. The results, as well as explanatory material, are presented in Appendix D, Parts I and II. For a review of the relationships between environmental variables and fish standing crop and harvest, as well as a history of the development of multivariate analysis as a method for estimating crop and harvest, see Jenkins (1967; 1974; 1976) and Jenkins and Morais (1971).

PART III: THE FISHERY MODEL DATA BASE

Fish and Fish Food Compartments

24. Reservoirs contain many fish species which differ in some degree from others in environmental requirements. Foremost among the many requirements for survival of each species is food. Sometimes the differences in types of food eaten among species are striking. For instance, adult striped bass normally feed on other fish, whereas adult bigmouth buffalo primarily feed on zooplankton. Among similar fishes, sunfish for example, the different species often overlap in their food habits. Food preferences also change as fish grow; for example, largemouth bass feed on zooplankton when newly hatched but on other fish and benthic organisms when they become adults. Food preferences often change daily and seasonally, as any frustrated fisherman can testify. To complicate this picture still further, the same species of fish may eat different foods in different reservoirs. In attempting to describe reservoir fish populations and their food for modeling, it is necessary to simplify the above relationships by generalization.

25. Before any simplifications can be attempted, the food of the different fish species must be known. Appendix E details the food of 78 reservoir fish species. Generalized food categories were used to simplify the classification of hundreds of different food items eaten by fish. Results are expressed as a percentage of the total volume of

food in the stomach of each fish.

26. Food information was abundant for some well-studied species but scarce for many more. The variability in foods eaten with age of fish, season, and location of reservoir was high. To develop a reasonably manageable model of fish species and their foods, this variability was reduced to general statements on the food of fish. Table 3 details the food for 26 major groups of reservoir fish. The estimates presented in this table represent an attempt to average the food of each fish group by species, season, age, and geographical location. These results should be interpreted to represent the diet of the average adult fish in each group over an annual cycle. It is reemphasized that the tabulated data do not represent absolute values. Many of the data developed in the remainder of this study rest on these general assumptions of what fish eat. Because of the high variability in the foods eaten, no regional trends could be determined.

Description of fish food compartments

27. On the basis of information collected from food studies, the food resources of reservoirs were generalized to form five food compartments (Figure 2). In the fishery model, all reservoir fish feed from one or more of these compartments. A description of each food compartment follows.

28. Prey fishes. All prey species eaten by a predatory fish (piscivore) are included in this category. Young-of-the-year fish, minnows, and clupeids are the major prey resources.

Table 3

Fish Food Expressed as a Percentage of the Diet by Volume*

	Food					
Species or Species Group	Plant	Detritus	Benthos	Zooplankton	Fish	Terrestrial
Gars					100	
Bowfin					100	
Gizzard shad	10	80	5	5		
Threadfin shad (young)	30	50	10	10		
Threadfin shad (adult)	30	5	15	55		
Rainbow trout	5		60	15	10	10
Brook trout			90	5		5
Pickerels					100	
Carp	30	40	20	10		
Minnows	20		20	60		
Carpsuckers	15	65	5	15		
Suckers	15	65	5	15		
Hog suckers		80	5	15		
Buffalofishes	5	40	5	50		
Redhorses			100			
Bullheads	10	25	50		15	
Catfishes	10		10		80	
Madtoms		27	55		18	
Silversides			20	80		
Temperate basses			20	10	70	
Sunfishes	10	5	65		5	15
Black basses			8		86	6
Crappies	5	5	20	15	55	
Perches			20	20	60	
Freshwater drum		8	58		34	
All other species			100			

* Food categories are described in the text.

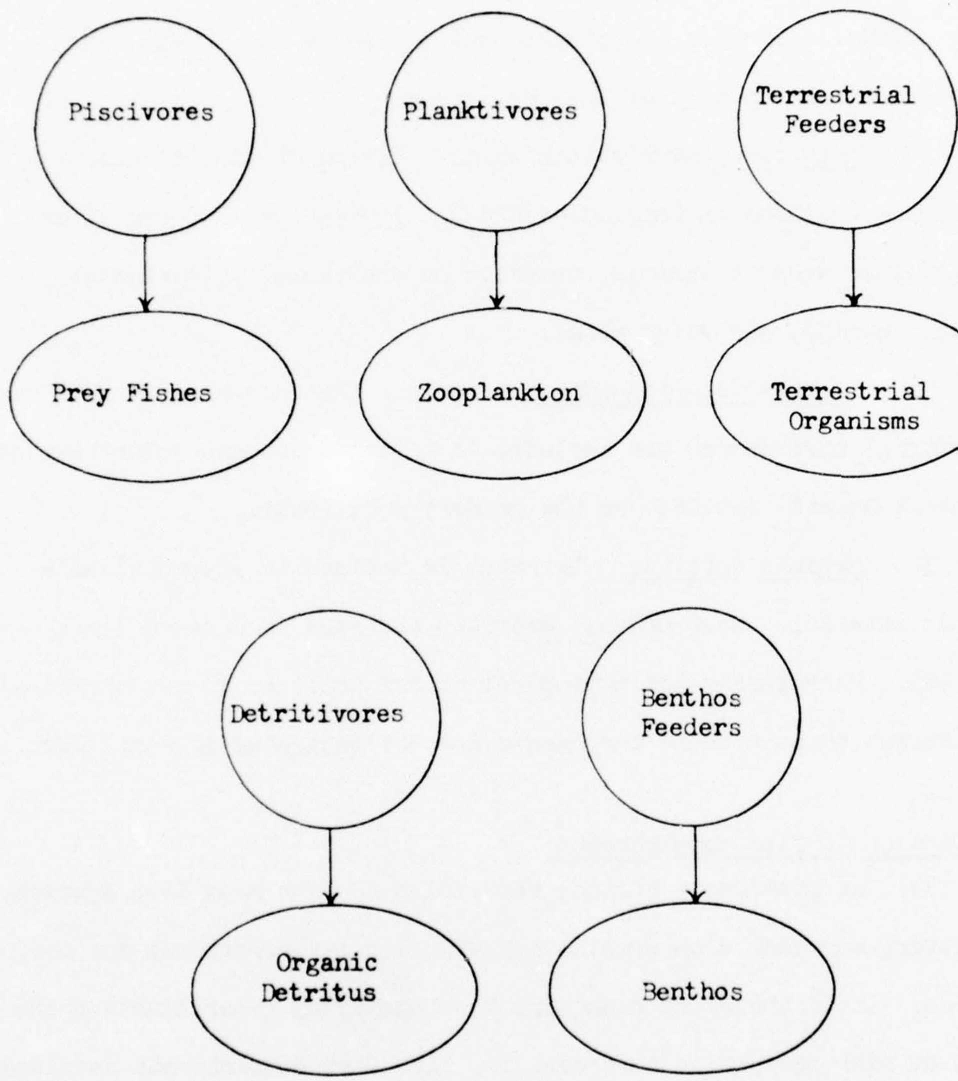

Figure 2. Schematic diagram of the relationship between fish and fish food compartments. (Circles represent fish compartments and ellipses represent fish food compartments)

29. Zooplankton. Zooplankters are small microscopic or nearly microscopic animals that drift passively or have weak mobility in the water column. Limnetic and planktobenthic species of copepods and cladocerans make up most of this compartment.

30. Benthos. Invertebrate animals living in, on, or near the bottom are included in this compartment. Typical benthic organisms are immature aquatic insects, crustaceans, molluscs, oligochaetes (aquatic worms), and water mites.

31. Terrestrial organisms. Organisms that normally inhabit the terrestrial environment are included in this compartment. Terrestrial and adult aquatic insects are the primary food items.

32. Organic detritus. Detritus is defined as unidentifiable organic material. Most organic detritus consists of decayed plant material. Macrophytes and phytoplankton are included in the detritus compartment because these components are not separated in most food studies.

Description of fish compartments

33. As previously stated, reservoirs contain many fish species. Attempting to model each species individually is impractical for obvious reasons. It is therefore necessary to simplify by generalization the types of fish present in a reservoir. Five fish compartments developed to correspond to the five fish food compartments outlined above are described here.

34. Piscivores. This group contains fish species that are all or in part piscivorous. Included are black basses, temperate basses,

crappies longer than 10 inches, catfishes longer than 18 inches, freshwater drum longer than 16 inches, and gars, bowfin, pickerels, pikes, and walleye. This group feeds on the prey fishes food compartment.

35. Planktivores. Fish included in this group are zooplankton feeders and include young-of-the-year fish of most species. Clupeids are the predominate fish group.

36. Benthos feeders and detritivores. Fish in these two groups are primarily bottom feeders. Most species included here are both detritivores and benthos feeders. The predominate species are adult shad, carp, freshwater drum less than 16 inches long, buffalofishes, carpsuckers, catfishes shorter than 16 inches, redhorses, crappies shorter than 10 inches, and various species of sunfish.

37. Terrestrial feeders. Fish that feed on terrestrial organisms primarily at the water surface are included in this compartment. Sunfishes and young black basses are the predominant terrestrial feeders.

Distribution of Fish Biomass Among Model Compartments

38. The fishery model is a mass balance model. For component parts of the model to be compatible, the units of measurement must be the same. The units used are biomass units expressed as pounds per acre. After fish and fish food compartments are established for modeling, a procedure was developed to distribute fish biomass to the appropriate compartment.

39. It was evident from Table 3 that, based on food habits, most

fish could be placed in several of the fish compartments. The biomass of each species or species group was proportioned among all of the compartments that characterize the foods eaten based on the percentage of food taken from each compartment. For example, temperate basses are benthos feeders, planktivores, and piscivores (Table 3). Twenty percent of the total biomass of temperate basses was assigned to the benthos feeder fish compartment, because 20 percent of the total diet of temperate basses was benthos. Likewise, 10 percent was distributed to the planktivore compartment and 70 percent to the piscivore compartment. Another way of stating the same information is that 20 percent of the temperate bass biomass is supported by the benthos food compartment, 10 percent by the planktivore food compartment, and 70 percent by the prey fishes food compartment. It was assumed that all foods are of equal nutritional value by volume.

40. Similar manipulations of fish biomass were performed for all fish species or species groups on a regional level. In this manner, fish biomass was distributed among the fishery model compartments. This distribution technique allowed a greater degree of realism in accounting for the tremendous variety in fish food habits than would a method that simply assigned the total biomass of each fish species to a fish compartment based only on the predominant food item eaten. Appendix F details the distribution of fish biomass, including annual production (see paragraphs 42 through 48, below), supported by each food compartment on a regional basis. The lack of sufficient information prevented completion of the analysis for all regions.

Concepts of Fish Carrying Capacity and Fish Production

Carrying capacity

41. Fish carrying capacity is a useful concept in reservoir management. It is defined as the standing crop of fish at the most critical period of the year for fish survival. This period is normally late winter or early spring. The concept of fish production is complementary to that of carrying capacity. Production is defined as the total living fish biomass produced in a given time interval. The elaboration of sex products has been excluded from the production definition. In practical terms, the time interval corresponds to seasonal growth from late spring to late fall of each year. Surplus production constitutes fish biomass added during the growing season minus natural mortality. Under stable conditions, surplus production does not survive the critical period of the year but is lost through natural and angling mortality and body weight loss.

Production and the relationship to growing season

42. Thompson (1941) hypothesized that because fish production may be expected to be proportional to total digestion, digestion being a function of temperature-influenced metabolic rates, it should be possible to express the relationship of production to carrying capacity at different latitudes. Thompson used digestive rates determined by Markus (1932) to derive values of maximum annual production as a percentage of carrying capacity, based on mean monthly air temperatures. Production varied from 21 percent of carrying capacity in Vilas County, Wisconsin, to 118 percent at New Orleans, Louisiana.

43. Jenkins and Morais (1971) found highly positive correlations between length of growing season and sport fish harvest, which prompted them to explore Thompson's hypothesis in relation to reservoir fish standing crop and harvest. They derived a curvilinear relation for growing season (frost-free period in days) versus the latitudinal production estimates of Thompson (Figure 3). This relation approximated the relationship found between standing crop of sport fishes and harvest in 15 predominantly southern reservoirs. The above relation is useful in estimating carrying capacity and annual fish production for reservoirs and has been used extensively in this study.

44. The growing season-production relation can be used to estimate carrying capacity and annual production not only for individual species and reservoirs but also for drainage areas, as the following example illustrates.

EXAMPLE: The average standing crop for all reservoirs in the White River Basin is 300 pounds per acre at the time of cove sampling in August. By August, 60 percent of the annual growing season of 200 days is over. The relation between growing season and production predicts that the maximum annual production for a 200-day growing season will be about 70 percent of carrying capacity (Figure 3). The relation of carrying capacity to August standing crop can be written:

$$\text{Carrying capacity} + 0.6\ (0.7\ \text{carrying capacity}) = \text{standing crop,} \qquad (1)$$

which rearranges to:

$$\text{Carrying capacity} = \text{standing crop}/1.42$$

e.g.:

White River reservoir carrying capacity = 300/1.42 = 211 lb/acre and the expected maximum annual surplus production is:

$$\text{Annual production} = 0.7\ (211) = 148\ \text{lb/acre}$$

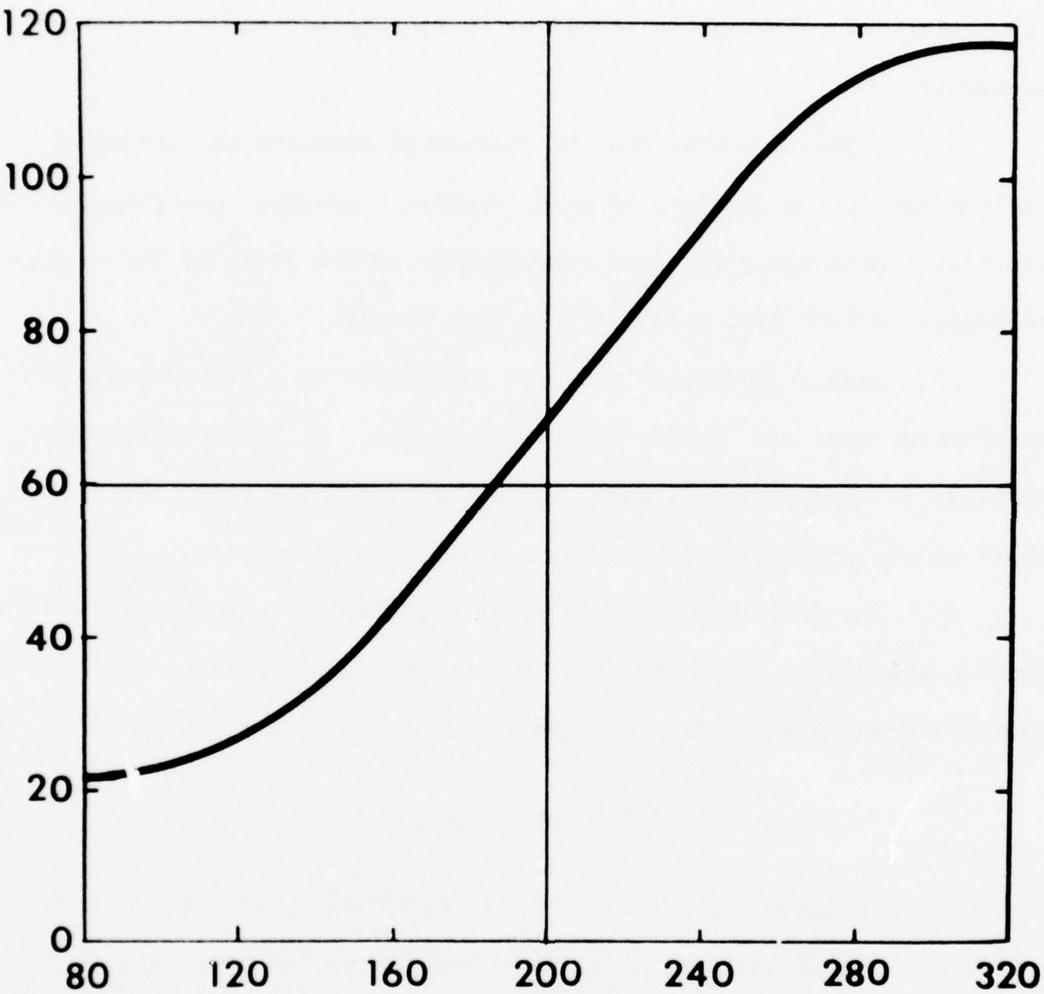

Figure 3. Hypothetical relationship of average annual length of growing season (frost-free period in days) to maximum annual fish production as a percent of carrying capacity. (The regression formula, where X is growing season in days and Y is maximum production as a percent of carrying capacity, is $Y = 81.73 - 1.516X + 0.01099X^2 - 0.00001845X^3$.)

45. The growing season-production relationship may not predict sound estimates for new reservoirs. These reservoirs have initial high fertility and fast turnover rates and may produce more than predicted. The postulated relationship should be reasonable for older, more stable reservoirs.

46. Appendix G presents the calculated carrying capacities of various species, summarized by major reservoir groups. Carrying capacity was distributed among the food compartments on the basis of the proportionality routine used to distribute fish biomass.

47. Annual production was also determined on a regional basis by drainage area but not for individual species; it is presented in Appendix F. Production is also distributed among the food compartments based on the proportionality routine previously described.

48. The distribution of carrying capacity and expected annual surplus production among the food compartments also reflects the biomass distribution among the fish species compartments of the model.

Fish Reproduction

49. For modeling purposes, fish reproduction has been defined as the biomass of young fish existing just before the beginning of their second growing season. This corresponds to the time of annulus formation when the fish are not quite one calendar year old. To rephrase the definition of reproduction, it is the production of young fish that survive from hatching through the critical period of the following spring.

50. Published data on fish reproduction in a form and detail necessary for the fishery model are not available in the literature. Therefore, the growing season-fish production relationship shown in Figure 3 was used to estimate fish reproduction in CE reservoirs.

Estimating fish reproduction

51. Data for 21 Predator Stocking Evaluation (PSE) reservoirs (Jenkins and Morais 1977) were used to estimate fish reproduction rates in CE reservoirs. These reservoirs are in the eastern and southern United States. For each reservoir, two years of data (1972, 1973) were available on the standing crop of young-of-the-year fish. The growing season-production relationship was applied to these data and the expected annual production of all young-of-the-year fish was calculated. Annual production of young-of-the-year fish, after being corrected for mortality, was defined as fish reproduction for modeling purposes. Table 4 summarizes the results for all reservoirs in the sample in terms of carrying capacity. Considerable variability existed among reservoirs examined, but when all values were pooled and averaged, reproduction was estimated to be about 28 percent of carrying capacity, or 37 percent of the total annual production.

52. Two reservoirs from the above sample, Beaver and Bull Shoals, both on the White River in Arkansas, have extensive data on young-of-the-year production available. Data for 10 years on Bull Shoals and 8 years on Beaver were analyzed to develop an estimate of year-to-year variability in reproduction. Table 5 presents the results of this analysis, which indicate that total reproduction as well as reproduction

Table 4

Estimated Reproduction as a Percentage of the Carrying Capacity for 21 PSE Reservoirs in 1972 and 1973

Reservoir and State	Year 1972	1973	1972-73 Average
Jordan, Alabama	16.5	21.0	18.8
Mitchell, Alabama	36.2	25.5	30.8
Beaver, Arkansas	26.0	27.1	22*
Bull Shoals, Arkansas	27.8	67.7	33**
Greeson, Arkansas	23.2	46.2	34.7
Jackson, Georgia	34.3	24.8	29.5
Sinclair, Georgia	57.1	35.8	46.5
Deep Creek, Maryland	36.3	44.8	40.5
Barnett, Mississippi	32.6	61.8	47.2
Enid, Mississippi	26.1	14.4	20.3
Grenada, Mississippi	17.1	29.6	23.4
Okatibbee, Mississippi	24.0	23.8	23.9
Sardis, Mississippi	15.7	17.4	16.5
Badin, North Carolina	29.4	28.4	28.9
Gaston, North Carolina	9.6	17.7	13.6
Cherokee, Tennessee	31.8	29.1	30.4
Dale Hollow, Tennessee	7.5	20.7	14.1
Watauga, Tennessee	14.0	7.0	10.5
Bastrop, Texas	21.7	30.0	25.9
Cypress Springs, Texas	15.5	27.7	21.6
E. V. Spence, Texas	43.2	58.8	51.0
Average of all reservoirs			27.8
Average of all reservoirs, excluding Beaver and Bull Shoals			27.8

* Eight-year average.

** Ten-year average.

Table 5

Production and Reproduction Estimates for Beaver and Bull Shoals Reservoirs*

Item	Beaver: Range of Values	Beaver: Average Value	Bull Shoals: Range of Values	Bull Shoals: Average Value	Average of Two Reservoirs
Production of all Y-O-Y** fish as a percentage of the total annual production.	8-50	33	5-95	57	45
Reproduction as a percentage of the carrying capacity.	16-30	22	3-163	33	28
Reproduction of Y-O-Y shad as a percentage of the total Y-O-Y reproduction.	38-93	79	6-76	48	64
Reproduction of Y-O-Y predators as a percentage of the total Y-O-Y reproduction.	5-60	18	7-88	36	27
Reproduction of all other Y-O-Y fish as a percentage of the total Y-O-Y reproduction.	<1-7	3	5-59	16	9

* Estimates are based on 10 years of data for Bull Shoals and 8 years of data for Beaver.

** Y-O-Y is the abbreviation for young-of-the-year (fish).

by various types of fishes is highly variable from year to year. The average value for total reproduction for both reservoirs in combination was 28 percent, which was identical to the average reproduction of all 21 reservoirs discussed previously.

53. If fish reproduction in Beaver and Bull Shoals reservoirs can be considered typical of the White River Basin, the following relationships would apply regionally: the White River Basin carrying capacity is 211.4 pounds per acre; reproduction is then 52.9 pounds per acre. Of this reproduction, 64 percent or 33.8 pounds per acre is contributed by shad; 27 percent or 14.3 pounds per acre by predators; and 9 percent or 4.8 pounds per acre by all other species.

Regional variations

54. Insufficient data exist at present to statistically demonstrate regional variation in reproduction rates. Data are lacking for most areas of the country, but it can be anticipated that regional differences in reproduction rate do exist. The above data suggest that reservoirs of the Lower Mississippi drainage and Tennessee Valley have lower reproduction than the average value derived in this analysis.

55. The contributions of the various fish compartments to total reproduction can change, depending on fluctuating environmental characteristics and reservoir fish species composition. Because the contribution of each fish compartment to total reproduction cannot be determined directly from the data available, an indirect method has been used. Reproduction by each fish compartment has been assumed to make the same percentage contribution to total reproduction as the percentage

recruitment contribution by each compartment makes to total recruitment (see Fish Recruitment). It is assumed that recruitment to a fish compartment is directly proportional to that compartment's reproduction. A further assumption is that there is no differential mortality of prerecruits among the fish compartments. Data for the 21 reservoirs examined previously were analyzed by this technique (Table 6).

56. Most young-of-the-year fish produced by the fish compartments do not feed on the same food as adults. This created a problem in data analysis because most young fish did not belong to the same fish compartment as the adults. The apportionment of young-of-the-year fish among the food compartments was achieved by using the proportion-of-diet method employed to distribute fish biomass and production, except that the diet of young-of-the-year fish was substituted. Table 7 summarizes the results for drainage areas or particular reservoir groups on the basis of CE reservoir data. Most drainage areas were excluded from analysis because few or no fishery data were available.

57. The above data represent the total production of age 0 fish. Only a portion of this total was present in the system at a given time and an undetermined amount represented production that would be lost during the year through mortality and anabolic activities. An example is offered to illustrate this point: if the average growing season were 215 days, as it is for the 21 PSE reservoirs used to estimate reproduction, about 25 percent of the annual production would have occurred by 1 June, 50 percent by 1 July, 75 percent by 1 August,

Table 6

Contribution of Each Fish Compartment to Total Reproduction

Fish Compartment	% Contribution to Total Reproduction
Piscivores	20
Planktivores	30
Benthos Feeders	25
Terrestrial Feeders	5
Detritivores	20

Table 7

Annual Reproduction Supported by Each Food Compartment

Drainage Area or Reservoir Group	Number of Reservoirs	Food Compartments* Detritus lb/acre	Detritus % TR	Benthos lb/acre	Benthos % TR	Zooplankton lb/acre	Zooplankton % TR	Fish lb/acre	Fish % TR	Terrestrial lb/acre	Terrestrial % TR	Total lb/acre	Total % TR
White River	6	17.8	26.7	9.3	14.0	35.9	53.9	2.4	3.6	1.2	1.8	66.6	100
Red River	6	16.6	26.8	8.6	13.9	33.4	54.0	2.2	3.6	1.1	1.8	61.9	100
Arkansas River**	15	35.7	25.4	19.5	13.8	76.1	54.0	5.0	3.6	2.5	1.8	140.8	100
Blue Mt., Nimrod, and Wister	3	44.3	27.8	30.2	18.9	71.8	45.0	8.9	5.6	4.4	2.8	159.5	100
Green and Cumberland Rivers and Dewey Reservoir	8	16.3	26.7	8.5	13.9	33.0	54.0	2.2	3.6	1.1	1.8	61.1	100
Lower Mississippi Valley	5	22.0	27.6	14.2	17.8	37.5	47.0	4.1	5.1	2.0	2.5	79.8	100
Gulf and South Atlantic	10	9.9	27.8	6.4	18.0	16.8	47.2	1.8	5.0	0.9	2.5	35.6	100
Buckhorn, Sutton, Summersville, and Flannagan	4	3.9	29.5	3.8	28.8	3.5	26.5	1.3	9.8	0.6	4.5	13.2	100
Weighted Average		21.6	26.4	12.4	15.2	42.2	51.6	3.3	4.1	1.7	2.1	81.7	100
Percent of average total carrying capacity (260.6 lb/acre)		8.3		4.8		16.2		1.3		0.6		31.4	

* TR = Total Reproduction.

** Excluding Blue Mountain, Nimrod, Wister, and Great Salt Plains.

and 100 percent by 1 November (Figure 4). A net loss in biomass would occur after November, until the next growing season.

58. Figure 4 illustrates the simplest case where carrying capacity is stable and does not change annually. In reality, carrying capacity may vary widely from year to year depending on environmental conditions. The carrying capacity of biomass elaborated during the growing season is determined by the environmental conditions of the succeeding winter and spring.

59. Caution should be exercised in using any of these results. No information is currently available for testing the assumptions of the analysis.

Fish Recruitment

60. Recruitment was defined as the addition of new fish to the vulnerable population by growth from among smaller size categories (Ricker 1975). The vulnerable population consisted of those size classes of fish subject to the sport or commercial fishing effort. For modeling purposes, biomass was recruited rather than numbers of fish. Estimating recruitment by using standard techniques such as recruitment curves, required information on the spawning stock, fecundity, and mortality of each species. These data were unavailable for mixed species populations of reservoir fishes. An alternative method of estimating recruitment, and the one used in this study, was to set a minimum size at which each species was recruited.

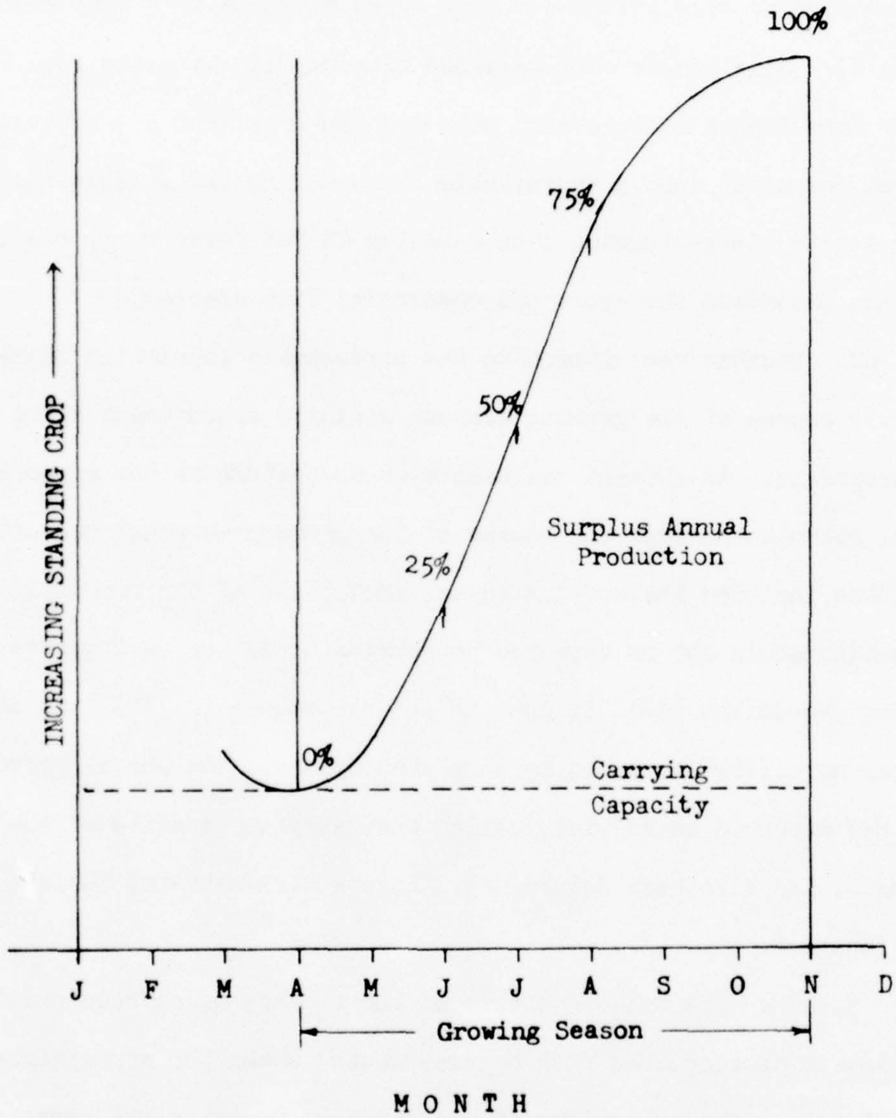

Figure 4. Relationships among standing crop, surplus annual production, carrying capacity, and time of year for 21 PSE reservoirs.

61. Using the data of Hayne et al. (1967), major groups of fish or fish species were assigned a size range at which they were recruited (Table 8). Size ranges were assigned because fish normally grow through one or more length classes each year and can grow from a length class not yet recruited into a recruitable class during the growing season. Using length class-standing crop data for 23 PSE reservoirs, recruitment was then estimated for sport and commercial fish species.

62. Because recruitment to the harvestable population increased over the course of the growing season, a single recruitment value was inappropriate. An attempt has been made to distribute the expected annual recruitment over the course of the growing season. Recruitment estimates included the surplus annual production of the recruits. This production would not be expected to survive until the next year's growing season but would be lost to natural causes (weight loss and natural mortality) or would be harvested by man. The annual recruitment that was expected to survive, called the carrying capacity of the recruits, has also been determined. Figure 4 illustrates these relationships.

63. The mass balance nature of the fishery model required that the biomass of recruited fish be distributed among the appropriate fish compartments. The apportionment was achieved by using the same technique as outlined for fish biomass data, based on fish food habits at the time of recruitment (Table 9). Tables 10 and 11 summarize the distribution of recruitment among food, and hence, fish compartments.

Table 8

Length at Recruitment for Reservoir Fish Species or Species Groups

Category of Fish	Total Length in.
Sport Fish	
Catfishes*	8-10
Temperate basses	8-10
Black basses	8-10
Crappies	8-10
Sunfishes	6-7
Walleye	8-10
Pike and Pickerels	8-10
Yellow Perch	8-10
Carp*	8-10
Commercial Fish	
Shad	5-6
Gars	18-20
Bowfin	18-20
Catostomids	11-13
Freshwater drum	7-9

* Considered both a sport and commercial species.

Table 9

Fish Food at Recruitment Expressed as a Percentage of the Diet by Volume

Species or Species Group	Food					
	Plant	Detritus	Benthos	Zooplankton	Fish	Terrestrial
Carp	30	40	20	10		
Catfishes	10	5	40	5	40	
Temperate basses			20	10	70	
Sunfishes	10	5	65		5	15
Black basses			8		86	6
Crappies	5	5	20	15	55	
Walleye					100	
Salmonids	5		60	15	10	10
Buffalofishes	5	40	5	50		

Table 10

Distribution of Recruitment by Food Compartments and Date for 23 PSE Reservoirs

Category of Fish and Date	Food Compartments*													
	Plant Material		Detritus		Benthos		Zooplankton		Fish		Terrestrial		Total	
	lb/acre	% TCC	lb/acre	% TCC	lb/acre	% TCC	lb/acre	% TCC	lb/acre	% TCC	lb/acre	% TCC	lb/acre	% TCC
Sport Fish**														
1 April	2.8	1.0	1.9	0.6	13.8	4.8	1.3	0.4	9.2	3.2	2.4	0.8	31.3	10.8
1 Jun	3.3	1.1	2.3	0.8	16.3	5.6	1.5	0.5	10.9	3.8	2.9	1.0	37.2	12.9
1 July	3.9	1.3	2.6	0.9	18.9	6.5	1.8	0.6	12.6	4.4	3.3	1.1	43.1	14.9
1 August	4.4	1.5	3.0	1.0	21.5	7.4	2.0	0.7	14.3	4.9	3.8	1.3	48.9	16.9
1 November	4.9	1.7	3.4	1.2	24.1	8.3	2.2	0.8	16.0	5.5	4.2	1.4	54.8	18.9
Commercial Fish† ††														
1 April	1.3	0.4	2.9	1.0	4.1	1.4	2.8	1.0	3.7	1.3	0	0	14.8	5.1
1 June	1.6	0.5	3.4	1.2	4.9	1.7	3.3	1.1	4.4	1.5	0	0	17.6	6.1
1 July	1.8	0.6	4.0	1.4	5.6	1.9	3.8	1.3	5.1	1.8	0	0	20.4	7.0
1 August	2.1	0.7	4.5	1.6	6.4	2.2	4.4	1.5	5.7	2.0	0	0	23.1	8.0
1 November	2.4	0.8	5.0	1.7	7.2	2.5	4.9	1.7	6.4	2.2	0	0	25.9	9.0

* TCC = Total Carrying Capacity = 289.2 lb/acre.

** Carrying capacity of sport fish recruits = 31.3 lb/acre. Expected annual surplus production of sport fish recruits = 23.5 lb/acre.

† Carrying capacity of commercial fish recruits = 14.8 lb/acre. Expected annual surplus production of commercial fish recruits = 11.1 lb/acre.

†† Catfishes and carp are included here as well as in the sport fish recruitment estimate. Shad are excluded.

Table 11

Percentage of Total Annual Recruitment Supported by Each Food Compartment

	Plant Material	Detritus	Zooplankton	Benthos	Fish	Terrestrial	Total
Sport Fish	9	6	4	44	29	8	100
Commercial Fish	9	19	19	28	25	0	100

The recruitment values in Table 10 for 1 April represent the initial standing crops of the recruits at the beginning of the growing season, which is also the carrying capacity. The carrying capacity of sport fish recruits averaged 11 percent of total carrying capacity for all reservoirs combined for both years. Individual values varied from 2.1 to 28.5 percent. Reservoirs of the Arkansas and White Rivers appeared to have lower recruitment rates than the other reservoirs. However, insufficient data exist to statistically demonstrate the validity of these rates. Commercial fish species had a carrying capacity of recruits that is about 5 percent of the total carrying capacity.

64. Recruitment estimates were based on a predominantly southern sample of reservoirs. Caution must be exercised in attempting to extrapolate these data to other regions of the country. For instance, salmonids were not represented in sport fish biomass in the reservoirs sampled. They were, however, the predominant sport fish in other areas of the country (Appendix C, Part I). A further complicating factor was the length of growing season. Jenkins (1974) has described the hypothetical relationship of growing season to fish production. Generally, the longer the growing season, the greater the fish production (Figure 3). The PSE reservoirs had an average growing season of 215 days, which meant that the fish production during the growing season would be about 75 percent of the carrying capacity. This relationship would not be true of a reservoir, say in the Missouri Basin, that had a growing season of 160 days where fish production would be about 40 percent of carrying capacity.

65. Data are lacking for the estimation of recruitment for reservoirs in other regions of the country. The suggested approach for estimating recruitment when a data base is lacking is to use the relationship between recruitment and total carrying capacity. For example, benthos-feeding sport fish recruits on 1 July made up 6.5 percent of the total carrying capacity in PSE reservoirs (Table 10). Assuming that the 6.5-percent relationship is relative and is a reasonable estimate regardless of geographical location, carrying capacity and growing season can vary. It is necessary to know carrying capacity, which has already been determined (Appendix G). Only the calendar dates between which growth occurs need to be reset and the percentage of total growth occurring by a given date properly proportioned.

66. The technique used in estimating recruitment may, in some cases, overestimate the correct value. This is especially true if much of the sport fish biomass is contributed by sunfishes, since sunfish recruited at a length of 5 and 6 inches are near their maximum size. At this size, sunfish of several year classes tend to accumulate. Fish recruited in previous years showing little additional growth could conceivably still be within this size range and hence recounted in the recruitment estimate.

67. A comparison of estimated recruitment rates (Table 10) with estimated harvest rates (Appendix C) indicates that sufficient fish are usually recruited to replace those that are harvested.

Distribution of Fish Harvest Among Model Compartments

68. Sport and commercial fish harvests for CE reservoirs were described in Part II of this paper. The mass balance nature of the fishery model required that the biomass of harvestable fish be distributed among the appropriate fish compartments. The apportionment was achieved in this analysis, as before, by distributing the biomass of each harvested species among compartments in direct proportion to the percentage of diet by volume eaten in each food compartment (Table 9). For example, black basses at recruitment ate 8 percent benthos, 86 percent fish, and 6 percent terrestrial food items. Therefore, 8 percent of the biomass of black basses harvested was assumed to have come from the benthic-feeding fish compartment, 87 percent from the piscivorous fish compartment, and 6 percent from the terrestrial-feeding fish compartment. Plant material has been separated from detritus in this analysis, but it may be desirable to combine these two food compartments. The division between plant material and detritus is usually made by an arbitrary judgment. Appendix H, Parts I and II, summarizes the distribution of harvest among the food, and hence, fish compartments.

Fish Growth Rates

69. Estimates of specific growth rates under laboratory conditions and for long time periods were available for only a few fish species. Many laboratory investigations in which growth rates were studied were not concerned principally with determining the maximum rates attainable.

Those studies attempting to determine maximum growth rates under varying conditions (i.e., photoperiod, temperature, or food ration) usually tested young fish less than age II. These fish have high growth rates and the application of their maximum growth rates to mixed species and mixed aged populations in reservoirs may not be valid. A further hindrance to using results from the literature, whether they be from laboratory or field, was that most results were presented in terms of growth in length, not in weight. Many authors failed to indicate the length-weight relationships so that the data cannot be converted. Others failed to include the exact time period over which growth occurred.

70. The data presented in Appendix I represent the maximum growth rates found in the literature for 46 reservoir fish species. The literature survey was not exhaustive but represented an examination of over 230 papers dealing with fish growth in weight. Some species are represented by only a single citation while others have as many as 30 references with data for all major climatic areas of the country. Growth had to be expressed as a rate between age classes, because information on growth in weight between length classes that included time period information necessary to derive per-day rates was unavailable. The tabular data under "age-class I" represent growth rates for fish from age 0 to age I, and under "age-class II", for fish from age I to age II, and so on. Papers cited in Carlander (1969 and unpublished) represented 60 percent of the papers examined in compiling growth rate data.

71. The youngest fish, both in the laboratory and in the field, have the highest specific growth rates and the oldest fish the lowest.

Ideally, to derive a maximum growth rate for a reservoir fish population, one would weight the maximum growth rate of each species at each age class by the corresponding biomasses and arrive at an overall weighted average. Insufficient data exist to attempt this for any reservoir, so an alternative approach must be used. In a mixed species reservoir population, the greatest biomass of fish is usually in age-class II or III. Therefore, to obtain the best estimate of maximum growth rate for the reservoir fish population as a whole, it is necessary to determine the maximum growth rate for fish in age-class II or III. This value should be less than the high growth rate of fish younger than age II but greater than the low growth rate of fish older than age III. Field study data must be relied upon heavily in estimation because laboratory data are scant. The authors believe that the estimates will approximate the maximum population growth rate. High specific growth rates of young fish that make up a small percentage of the total biomass are balanced by the low specific growth rates of old fish that usually make up a greater percentage of the biomass.

72. At this time there appears to be no difference statistically in maximum specific growth rates among the proposed fish compartments of the model. Reasonable estimates for the maximum specific growth rate range from 0.007 to 0.015 per day, with the most favored value being 0.010 per day.

Half-Saturation Constants for Fish Growth

73. The concept of half-saturation constants or dissociation constants, has its origins in enzyme-substrate kinetics theory as first expressed by Michaelis and Menten (1913). They developed an equation to express the relationship of the rate of a chemical reaction as a function of the maximum reaction rate possible, the concentration of the material reacting, and a constant, known as a dissociation or half-saturation constant. Biologists have used the Michaelis-Menten relationship, as it is known, to describe many rate-dependent phenomena in living systems.

74. The fishery model uses half-saturation constants to adjust the growth rate of fish to the available food supply. The half-saturation constant is actually the amount of food ingested that results in fish growing at half the maximum growth rate. This relationship can be described as follows:

$$v = V_{max} \left(\frac{S}{K_s + S}\right) \qquad (2)$$

where: v = actual growth rate

V_{max} = maximum growth rate

S = food concentration ingested

K_s = half-saturation constant

75. It was found that the relation of fish growth to food consumption does not closely follow the above Michaelis-Menten relationship.

76. Transformations of fish growth-food consumption data, following Michaelis-Menten (Case I) (Lineweaver and Burk 1934), indicate

that fish growth can obtain infinite velocity at a finite food level. Obviously, this is untrue. Further transformations developed to analyze more complex enzyme-substrate interactions (Cases II through VI) fail to accurately model fish growth-food consumption relationships. Case VII (Diffusion) most closely fits the available data. The form of this relationship is:

$$v = V_{max}\ k_1'\ (S)/(V_{max} + k_1'\ K_s\ (S) - v) \qquad (3)$$

where: k_1' = velocity constant

This relationship was used to estimate the half-saturation constant K_s for all data sets.

77. Numerous laboratory studies have examined the influence of food ration quantity on fish growth. However, few of these studies have examined the growth-food consumption relationship in enough detail to allow an estimate of the half-saturation constant to be made. Many studies are statistically unreliable because conclusions are drawn from small sample sizes. Others fail to distinguish between the growth efficiencies of fish of different ages. Only Brett et al. (1969) examined the temperature effects on the growth-food consumption relationship and also included sufficient detail to estimate half-saturation constants.

78. Data drawn from six laboratory studies were analyzed to estimate half-saturation constants; the results are presented in Table 12. Young fish were tested by Williams (1959), Gammon (1963), Brett et al. (1969), and Andrews and Stickney (1972). Because the growth rates of these fish are higher than for older, slower growing fish, the estimated

Table 12

Estimated Half-Saturation Constants for Fish Growth

Species	Length and/ or Weight	Water Temperature °C	Calculated Maximum Growth Rate Expressed as % of Body Weight Gained Per Day	Calculated Half-Saturation Constant (K_s) Expressed as % of Body Weight Consumed Per Day	Type of Food	Reference
Largemouth bass	24.5 cm	21	3.9	4.6	minnows	Thompson (1941)
Smallmouth bass	8.3-20.2 cm 4-112 g ($\bar{x}$ = 40 g)	21.3	4.7	7.2	minnows	Williams (1959)
Muskellunge	17.0 cm 17.0 g	19.5	3.9	5.6	minnows	Gammon (1963)
Reticulate sculpin	1.2 g	11.6	1.7	4.4	midge larvae	Davis and Warren (1965)
Channel catfish	4 g	30	3.4	3.1	mixed diet	Andrews and Stickney (1972)
Sockeye salmon	6.9 g	10	1.8	3.9	mixed diet	Brett et al. (1969)
Sockeye salmon	7.1 g	15	4.2	7.9	mixed diet	Brett et al. (1969)

half-saturation constants will be high. Thompson (1941) presented data for a 10-inch largemouth bass. A bass of this size represents a typical reservoir predator. Only two data sets were available for benthos-feeding fish: the channel catfish data of Andrews and Stickney (1972) which are limited and should be treated cautiously; and the Davis and Warren (1965) investigation, which studied yearling reticulate sculpins under cold-water conditions.

79. One would expect the half-saturation constant to increase as water temperature increased. After the fingerling sockeye salmon studied by Brett et al. (1969) were fed an omnivorous diet, the authors concluded that $15^{\circ}C$ was optimum for growth. A substantial change in the half-saturation constant as the temperature increased from 10° to $15^{\circ}C$ was noted. At present insufficient data exist to demonstrate different half-saturation constants for piscivores and benthos feeders. No data could be located for detritivores or planktivores.

80. Estimates of the half-saturation constants using Lineweaver-Burk transformations must be treated cautiously. Based on the analysis of the estimated half-saturation constants, and considering the influence of fish size, it is suggested that initially K_s be considered 5 percent of fish wet body weight per day at $20^{\circ}C$. Five percent of the body weight consumed per day corresponds closely with the food intake rate for optimum efficiency in growth (4 to 5 percent for many species). Additionally, food consumption at this level will result in a growth rate that corresponds to the maximum growth rate observed in the field for some species.

81. Because Michaelis-Menten relationships do not closely fit fishery data, it is questionable whether or not the enzyme kinetics theory is conceptually applicable to fish populations. The analysis of relations between fish food consumption and fish growth may require the development of a new theoretical framework. No attempt has been made here to advance a new approach in developing fish growth half-saturation constants.

82. V_{max} and K_s are constants under specified conditions. In nature, however, conditions rarely ever remain constant. For instance, as a fish swims through the environment, it encounters differing concentrations of different foods. Different types of food may have different palatabilities to the fish. Thus in nature K_s and V_{max} may appear to vary continually (Parker 1975). Parker has shown that if the Michaelis-Menten equation is used to describe food ingestion by fish, constant values for V_{max} and K_s do not reproduce observed stomach contents. When both V_{max} and K_s were allowed to vary with the availability of alternate foods and the relative preference of these foods, the expected stomach contents agreed closely with actual observation.

Digestive Efficiencies of Fish

83. Knowledge of energy transfer from one trophic level to another is important in understanding fish population dynamics and the relationship of fish populations to other biological systems in reservoirs. Information on energy use and transfer can be obtained by studying

fish digestive efficiencies. Digestive efficiency, in broad terms, indicates how the food a fish eats is used for growth and other physiological functions. The energy budget for food consumed by a fish can be written (after Warren and Davis 1967) as:

$$C = F + U + R + \Delta B \qquad (3)$$

where: C = energy consumed (ingestion)

F = energy egested (egestion)

U = energy lost as excretory products (excretion)

R = energy of respiration

ΔB = energy accumulated as growth

84. In this report information on two measurements of fish digestive efficiency is summarized: ecological growth efficiency and assimilation efficiency. Data on the food consumption requirements of various fish species are also presented. No attempt has been made to interpret the relationship of ecological growth efficiency or assimilation efficiency to fish age, condition, food availability, or other environmental characteristics. The reader is referred to Warren and Davis (1967) for an excellent review of fish feeding, bioenergetics, and growth.

85. Ecological growth efficiency has also been called gross growth efficiency and is defined as: $\Delta B/C \times 100$. Ecological growth efficiency expresses the relationship of fish growth to total food consumption. Appendix J summarizes data on ecological growth efficiency. Values range from 4.2 percent for a wild population of bluegill to 62.5 percent for young channel catfish under controlled laboratory conditions. For

carnivorous fish species, Winberg (1956) found the average ecological growth efficiency to be 20 percent. This 20-percent value is widely accepted in the literature as representative of most fish species.

86. Assimilation efficiency is defined as

$$A/C \times 100 \tag{4}$$

where: A = energy assimilated = $C - F - U$

Appendix J summarizes assimilation efficiencies for fish. Assimilation efficiency in fish is high, ranging from 66 to 98 percent. Many workers consider 80-percent assimilation efficiency realistic for most fish species.

87. Appendix J also lists the daily food consumption of fish, expressed as a percentage of body weight. Data on the daily meal of fish are useful in calculating energy budgets and for determining the amount of food necessary to support a fish population. Daily meals vary widely depending upon fish age, availability of food, and other environmental variables. In general, food amounting to 1 percent of the body weight per day is needed for maintenance without growth, and 4 to 5 percent of the body weight per day is required for optimum growth efficiency.

Fish Mortality Rates

88. The fishery model currently defines mortality rate as that fraction of the fish biomass that is converted to detritus by death. Modifications in the model will be necessary to account for fish biomass

lost by predation to piscivorous fish. Estimates of the ecological growth efficiency of carnivorous fish indicate that 20 percent of the fish biomass lost to predators will be incorporated as new fish biomass through growth, and the remaining 80 percent will continue along the detritus pathway in the form of egested material and feces (Winberg 1956).

89. The results of a review of the natural mortality rates of 17 species of reservoir fish are presented in Appendix K. This review is not extensive. It does, however, adequately demonstrate that natural mortality can be highly variable, depending on fish species, fish age, exploitation rate, and numerous environmental variables. For exploited populations tabulated in Appendix K, the average natural mortality rate per day for all species is 0.001. There is no evidence for significantly different regional differences in mortality rate. Insufficient data are available to examine the possibility of differential mortality rates among fish compartments. In one study that was reviewed, Patriarche (1968) demonstrated seasonal differences in mortality rate. Seasonal mortality rates probably vary widely over the continent and from year to year within a single reservoir, depending upon fluctuating environmental conditions.

90. For an excellent review of techniques for calculating various mortality rates (total, instantaneous, conditional, natural, and fishing), the modeler is referred to Ricker (1975).

Fish Respiration Rates

91. All energy necessary for the maintenance, growth, and reproduction of fish is derived from the energy of assimilated food. Most of the energy is used in a series of chemical reactions within a fish known as metabolism. Metabolic processes keep the internal functions operating. Energy is also used in growth. An understanding of fish production processes requires a knowledge of the interactions of energy supply, metabolism, and growth (Beamish and Dickie 1967).

92. Respiration rates have been used to study fish metabolism. Metabolism is normally equated to oxygen consumption, with the assumption being that all energy is released aerobically. Small amounts of energy are, however, released anaerobically. Respiration rates can be used to determine what fraction of fish biomass is converted to inorganic carbon, nitrogen, and phosphorus by normal metabolic processes. Knowledge of the rate transfers of these three elements is necessary for the mass balance functions of the fishery model.

Types of respiration

93. Three types of respiration rates were examined in this study: standard, routine, and active.

94. Standard respiration. The oxygen consumed in the absence of measurable movement is standard respiration. Standard metabolism has also been termed nonactive, basal, or resting metabolism. Obviously standard metabolism can be difficult to measure as few fish species are completely quiescent for extended periods.

95. Routine respiration. The rate of oxygen comsumption of a fish showing normal activity is routine respiration. Routine respiration is often measured as the average oxygen consumption observed over a 24-hour period.

96. Active respiration. The maximum rate of oxygen consumption under continuous forced activity is active respiration.

97. It is beyond the scope of this report to attempt to review all the available information on the metabolic rates of fishes. For further information on this subject the reader is referred to the works of Winberg (1956), Fry (1957), and Beamish and Dickie (1967). This study attempted to draw general conclusions about fish respiration rates in support of the data requirements of the fishery model.

Effect of temperature and fish weight

98. The active metabolic rate in relation to temperature does not necessarily follow a course parallel to the curve for the standard rate. The active rate may continue increasing until the fish reaches its upper lethal temperature limit as in trout and catfish. It may reach a plateau as in goldfish, or it may actually be depressed at the higher temperatures, as in lake trout (Figure 5, Fry 1957). For these reasons, predictive equations of active metabolism based on linear regressions may not be valid, or they may be valid only over a limited temperature range (Appendix L, Part I).

99. In contrast, the standard metabolic rates of various fish species show a qualitative uniformity of response. Standard metabolism increases with increasing temperature and therefore is usually predictable based on linear regressions (Appendix L, Part II). Active metabolism

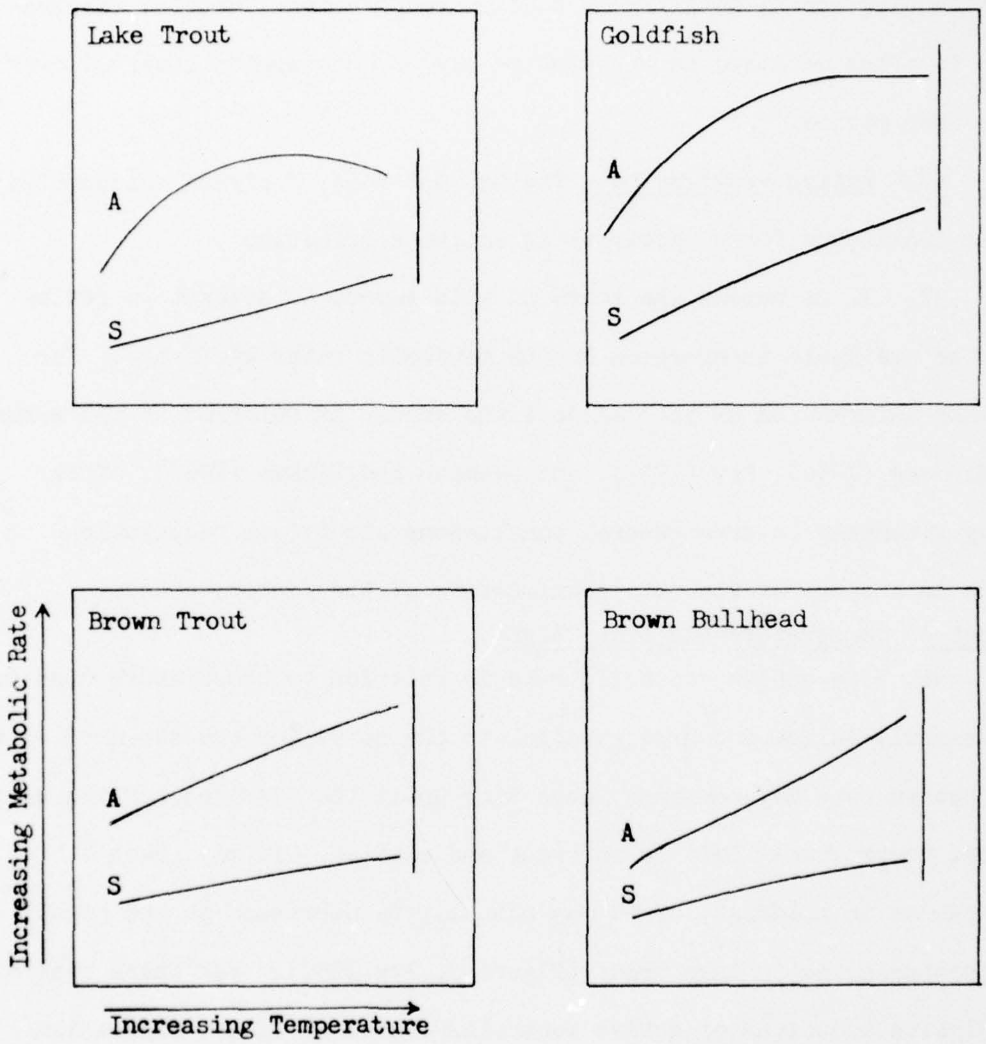

Figure 5. Active and standard metabolic rates of thermally acclimated fish (After Fry 1957). S = standard metabolic rate; A = active metabolic rate. Vertical lines represent upper lethal temperatures.

cannot be predicted a priori from the standard metabolism or the routine metabolism (Norstrom et al. 1976). Additionally, both active and standard metabolism are related to fish weight in most species. Metabolism increases with increasing weight of the fish, whereas, metabolism per unit weight usually remains the same or decreases with increasing weight. Both fish weight and temperature must be considered in predicting active and standard metabolism.

Effects of fish activity

100. Fry stated (Brown 1957), "An interesting point in connection with the oxygen consumption of fish is that the active rate of oxygen uptake is restricted to a few multiples of the standard rate." His data for several species showed that the greatest increases of the active rates are only of the order of four times the standard rates. However, for very active migrating species such as the sockeye salmon, Brett (1964, 1965) has shown that the active/standard ratio can exceed 16, depending on fish age. Most reservoir fish species are not as active as the sockeye salmon and consequently would have much lower active metabolic rates.

101. Winberg (1956) and Mann (1969), as well as other workers, are of the opinion that the metabolic rate of fish in confinement should be doubled to correct for activity in nature. The literature review given by Winberg (1956) indicates that this routine metabolism is approximately 1.7 times the standard metabolism (Appendix L, Part III). The relationship relating routine metabolism to standard metabolism is successful in predicting respiration rates over at least part of the normal temperature

range of various fish species (Solomon and Brafield 1972).

102. It would appear that the best estimate of the rate of respiration for normally active reservoir fish would be values for routine metabolism, such as those tabulated in Winberg (1956). Active metabolism rates as expressed in Appendix L, Parts I and III, indicate the maximum respiration rates for short time intervals. Fish do not usually respire at these rates for long periods, and therefore the values given overestimate the true average metabolism of normally active fish. Norstrom et al. (1976) considered active metabolism to be three times the routine metabolism.

103. It is suggested that routine respiration rates be used to estimate respiration in active fishes (Appendix L, Part IV). Routine metabolism can be estimated to be two or three times standard metabolism for reservoir fishes and four or five times the standard metabolism for active cold-water fish like salmonids.

Temperature Tolerances of Fish

104. Temperature tolerance limits define the range in which fish will grow and survive. Because the rates of most biological processes are temperature dependent, it is important to know the temperature limits an organism can tolerate and also its preferred temperature range for optimizing various physiological functions.

105. Temperature tolerance data for 45 reservoir fish species are presented in Appendix M, Part I. Appendix M, Part II, summarizes the

many temperature tolerance studies by species, and Table 13 presents a generalized temperature tolerance summary by fish groups. For most warm-water species, upper and lower temperature tolerances are similar, the lower limit being reached at $0^{\circ}C$ and the upper limit attained between 33° and $37^{\circ}C$. The optimum temperature for growth is centered close to $27^{\circ}C$. Cold-water species, such as salmonids, also reach a lower lethal limit at $0^{\circ}C$, but the upper lethal limit is near to $25^{\circ}C$ and optimum growth occurs at about $14^{\circ}C$. Temperature tolerance values presented in Appendix M were determined at various acclimation temperatures. In summarizing temperature tolerance limits (TL) by species (Appendix M, Part II), when more than one value was cited, the extreme temperature tolerances reported resulting in the survival of half the test fish for at least 24 hours are listed (24-hour TL 50)* if known.

Chemical Composition of Fish

106. Chemical composition data were used in the fishery model to maintain continuity of mass within the reservoir ecosystem by adding an appropriate amount of a particular constituent to the fish compartments through feeding and consequent growth and by returning mass due to fish respiration and decomposition as detritus.

107. Knowledge of the carbon, nitrogen, and phosphorus composition of fish is necessary for the mass balance functions. Table 14 presents these data for a variety of freshwater and saltwater fish species. In general, fish are 48 percent elemental carbon by dry weight (dry weight = weight after desiccation at $60^{\circ}C$ for 48 hours), 16 percent elemental

* A 24-hour TL 50 is the median toxicity that occurs within a 24-hour period.

Table 13

Temperature Tolerances for Various Fish Groups*

Species Group	Lower Lethal	Optimum for Growth	Upper Lethal
Pickerels	0	25.4	34.4
Minnows	0	27	33.4
Catfishes	0	30	37.1
Sunfishes	≤2.5	27.5	35.7
Black basses	≤1.6	27	36.5
Crappies		≈23	32.5
Yellow perch	0	24.2	30.9
Average values	0	26.3	34.8

* All values expressed in degrees Centigrade.

Table 14

Chemical Composition of Fish

Element and Species	% Composition		Reference
	Dry Weight	Wet Weight	
Nitrogen (N)			
Ocean sunfish (Mola mola)	16.6-18.2		Green (1899)
Bluegill	16.7		Calculated from data by Geng (1925), Gerking (1962), and Maynard (1951)
Bluegill		2.72	Gerking (1962)
Carp		2.6	Bull and MacKay (1976)
Northern squawfish		2.5 ± 0.1	
Largescale sucker		2.4	
Rainbow trout		2.9	
Channel catfish		2.35	Worsham (1975)
General average	16.3		Bailey (1937), Nottingham (1952)
Carbon (C)			
Ocean sunfish (Mola mola)	48.2		Green (1899)
Phosphorus (P)			
Salmon		0.59	Atwater (1892) As P_2O_5
Trout		0.81	
Cod		0.60	
Eel		0.68	
Haddock		0.97	
Halibut		0.44	
Herring		0.56	
Mackerel		0.56	
Turbot		0.48	
Average of above species		0.63	
Bluegill	4.75±0.70		Kitchell et al. (1975)
	4.73±0.85		± 1 S.E.
Bluegill	4.2		Hall et al. (1970)
Channel catfish		0.86	Worsham (1975)
Carp		0.5 ± 0.01	Bull and MacKay (1976)
Northern squawfish		0.4	
Largescale sucker		0.3	
Rainbow trout		0.4	
General average (for fish flesh)		0.22 (range: 0.1-0.4)	Clauseret (1962)

nitrogen, and 5 percent elemental phosphorus.

Recommendations

108. The recommendations presented suggest areas for further research to improve the fishery model data base. No attempt has been made to recommend improvements in the model itself or to address the problems of reservoir operation relating to fisheries management.

109. No matter how well conceived a model may be, its success in application depends largely on the quality of the data used to develop it. Large deficiencies in the data base exist for parts of the fishery model, and these deficiencies have been emphasized where applicable.

110. The authors have not attempted to present final answers to the many topics examined in this paper. Much of the material presented is developed for the first time and represents an attempt to provide a starting point in solving some very difficult and little studied aspects of modeling fish population dynamics. It is anticipated that some of the methodologies used will be subjected to criticism, and it is hoped that out of such criticism new approaches to modeling and a better understanding of fish populations will develop and be useful in future modeling efforts.

111. It is recommended that the following areas be studied further to improve the model data base:

1) Additional information needs to be collected and analyzed on the fishery resources of CE reservoirs, especially those reservoirs located in the northern and western United States. Of the 187 CE

reservoirs for which physical and chemical data were available, only 33 percent had any type of fishery statistics available. Most of the reservoirs with useable data were located in the south. For those reservoirs where fishery data were available, much of the information was fragmented. Most recent data covering more years need to be obtained to develop regional fishery coefficients.

2) A continuing program of analyzing fish food habits will help refine the fishery model compartments. These data should be gathered on CE reservoirs when possible. As much of the model is developed upon fish feeding habits, a good data base is critical.

3) Further work should be directed toward improving the method of distributing fish biomass among the food compartments. Improvement should attempt to account for the nutritional value and useable energy content of different food sources.

4) The data base for estimating fish reproduction is poor and an attempt should be made to obtain further information on fish reproduction, especially from nonsouthern reservoirs. New finds will probably be the source for this information.

5) Except for the southern United States, there is a complete lack of fish recruitment data of a type suitable for the model. New approaches toward estimating both reproduction and recruitment should be investigated.

6) The concept of half-saturation constants for fish growth may need to be developed from a new theoretical framework. The current

data base for estimating half-saturation constants is poor, and further refinements of these constants may be necessary.

7) Further data collection on the natural mortality rates of reservoir fishes is needed, especially seasonal mortality.

8) It is recommended that a continuous effort be made to review new literature for data directly applicable to fisheries modeling. New concepts in thinking about fish population dynamics should be explored. This may lead to improved model design and greater predictive precision.

APPENDIX A: PHYSICAL AND CHEMICAL DESCRIPTIONS OF 187 CORPS OF ENGINEERS RESERVOIRS GREATER THAN 500 ACRES IN SURFACE AREA

APPENDIX A

In the following tabulation, the reservoirs are listed alphabetically by drainage area. Definitions of characteristics listed in column headings are:

(a) Reservoir name - official name of impoundment; "Lake" omitted from name when occurring as part of the official name.

(b) State - two-letter postal abbreviation of the state name where the reservoir is located. Interstate reservoirs are placed in the state where the dam is located.

(c) CE Division - Corps of Engineers administrative division having responsibility for the reservoir.

(d) Year impounded - first year in which a significant volume of water was stored.

(e) Use type - arbitrary classification of reservoirs into major or principal use types.
Key: 1. Hydropower
2. All other uses including navigation, flood control, irrigation, water supply, or fish and wildlife.

(f) Chemical type - prevalent chemical type of inflowing rivers, according to Rainwater (1962). Composition of rivers of the conterminous United States. Hydrologic Investigations Atlas HA-61. Plate 2. U. S. Geological Survey. Delineation based on 50-percent breakpoint of major constituents, computed as equivalents/million.
Key: 1. Ca-Mg, CO_3-HCO_3 3. Na-K, CO_3-HCO_3
2. Ca-Mg, SO_4-Cl 4. Na-K, SO_4-Cl

(g) Sediment type - sediment concentration (annual load/annual streamflow) of inflowing rivers according to Rainwater (1962). (Reference above. Plate 3.)
Key: 1. 0-280 ppm 4. 6300-14000 ppm
2. 280-1900 ppm 5. 14000-28000 ppm
3. 1900-6300 ppm 6. 28000-38000 ppm

(h) Drainage area - in square miles.

(i) Surface elevation - in feet above mean sea level, of reservoir surface at listed area.

(j) Surface area - in acres at average annual pool level where data were available; otherwise, conservation pool, summer pool, operating pool, or power pool area is listed.

(k) Volume - expressed in thousands of acre-feet, at the listed elevation.

(l) Total annual discharge - expressed in thousands of acre-feet.

(m) Storage ratio - the ratio of the reservoir volume at the listed elevation in acre-feet to the average annual discharge in acre-feet.

(n) Mean depth - in feet, at listed surface area.

(o) Maximum depth - in feet, at listed surface area.

(p) Outlet depth - midline depth of principal outlet, in feet. Where multilevel outlets exist, mean depth of all outlets is listed.

(q) Thermocline depth - in feet, of top of thermocline (water temperature change of $1^{o}C$/metre) on or about 15 August. A plus sign (+) signifies that a stable thermocline does not form.

(r) Fluctuation - mean annual vertical fluctuation of reservoir surface level, in feet.

(s) Shoreline length - in miles.

(t) Shore development - the ratio of shoreline length to the circumference of a circle equal in area to that of the reservoir.

(u) Dissolved solids - residue on evaporation at $180^{o}C$, in ppm. Mean values calculated from available data; rounded to nearest 5 ppm where data were limited. Primary data sources - U.S.G.S. Water Resources Data - Part 2. Water Quality 1970-1975.

(v) Specific conductance - in micromhos per centimetre at $25^{o}C$. Primary data sources as referenced above.

(w) Growing season - average number of days between first and last frost. U. S. Weather Bureau data.

A dash (-) indicates data not available.

Reservoir Name a	State b	CE Division c	Year Impounded d	Use Type e	Chemical Type f	Sediment Type g	Drainage Area h	Surface Elevation i	Surface Area j	Volume k	Total Annual Discharge l	Storage Ratio m	Mean Depth n	Maximum Depth o	Outlet Depth p	Thermocline Depth q	Fluctuation r	Shoreline Length s	Shore Development t	Dissolved Solids u	Specific Conductance v	Growing Season w
New England Drainage Area																						
Colebrook River	CT	NED	1969	2	2	1	118	708	760	47	157	0.30	62	141	138	25	69	4	1.0	60	100	150
Waterbury	VT	NAD	1937	1	1	1	109	580	850	36	167	0.22	43	100	75	-	30	-	-	-	-	125
Middle Atlantic Drainage Area																						
Beltzville	PA	NAD	1971	2	2	1	96	628	947	41	153	0.27	44	124	11	20	0	20	4.7	75	115	150
Curwensville	PA	NAD	1965	2	2	1	365	1,162	790	10	451	0.02	12	32	21	18	7	19	4.9	125	190	120
John H. Kerr	NC	SAD	1953	1	1	1	1,780	302	53,100	1,530	5,283	0.29	29	112	67	35	11	770	23.9	70	100	205
Foster J. Sayers	PA	NAD	1971	2	2	1	339	630	1,730	29	308	0.09	17	42	33	12	20	23	4.0	150	275	150
Philpott	VA	SAD	1951	1	1	1	212	974	2,880	164	204	0.80	57	167	93	25	13	100	13.3	40	55	200
Raystown	PA	NAD	1972	2	2	1	960	786	8,300	514	797	0.64	62	181	52	20	7	118	9.2	130	155	150
Whitney Point	NY	NAD	1963	2	1	1	255	973	1,200	13	274	0.05	10	33	26	+	7	11	2.2	100	150	140
Gulf and South Atlantic Drainage Area																						
Allatoona	GA	SAD	1950	1	1	1	1,110	840	11,860	368	1,338	0.28	31	150	75	25	30	270	17.8	40	60	210
Claiborne	AL	SAD	1969	2	1	2	21,520	35	5,930	96	23,538	*	16	36	20	+	1	204	18.9	60	100	265
Clark Hill	GA	SAD	1952	1	1	1	6,150	330	70,000	2,510	6,004	0.42	36	144	75	35	8	1,060	28.6	55	80	230
Hartwell	GA	SAD	1961	1	1	1	2,088	660	56,000	2,550	3,071	0.83	46	195	105	25	8	962	29.0	30	45	210
Jones Bluff	AL	SAD	1971	1	1	2	16,300	125	12,510	234	17,200	0.01	19	50	25	+	1	368	23.5	55	80	270
Millers Ferry	AL	SAD	1968	1	1	2	20,700	80	17,200	331	20,500	0.02	19	64	36	+	1	516	28.1	55	80	265
Ocklawaha	FL	SAD	1968	2	2	1	2,840	18	9,050	60	1,409	0.04	7	31	12	+	1	67	5.0	260	460	285
Okatibbee	MS	SAD	1968	2	1	2	235	342	3,350	37	208	0.18	11	32	32	16	8	25	3.1	40	60	230
Seminole	FL	SAD	1957	1	1	1	17,150	77	37,500	367	15,986	0.02	10	40	25	+	2	250	9.2	50	75	250
Sidney Lanier	GA	SAD	1957	1	1	1	1,040	1,070	38,000	1,917	1,553	1.23	50	151	139	20	6	540	19.8	60	85	205
W. Kerr Scott	NC	SAD	1962	2	1	1	348	1,030	1,470	41	485	0.08	28	65	59	10	5	55	10.2	35	45	160
Walter F. George	GA	SAD	1962	1	1	1	7,460	190	45,180	934	7,935	0.12	20	96	18	+	6	641	21.5	60	90	240
Ohio Basin Drainage Area																						
Allegheny	PA	ORD	1967	1	2	1	2,180	1,325	11,600	537	2,729	0.20	46	127	110	35	50	91	6.1	190	255	120
Atwood	OH	ORD	1937	2	2	1	70	928	1,540	24	50	0.47	15	38	34	15	10	28	5.1	175	270	160
Barkley	KY	ORD	1966	1	1	1	17,598	359	57,920	869	25,759	0.03	15	80	49	+	5	118	3.5	100	175	200
Barren River	KY	ORD	1964	2	1	2	940	552	10,000	256	1,061	0.24	26	79	39	20	27	140	10.0	140	235	190
Berlin	OH	ORD	1943	2	2	2	249	1,019	2,600	41	162	0.25	15	70	61	18	25	64	9.0	330	490	150
Bluestone	WV	ORD	1949	2	1	1	4,603	1,409	1,970	37	4,051	0.01	19	39	1	+	48	33	5.3	-	-	174

(Continued)

* 0.004

Appendix A (Continued)

Reservoir Name a	State b	CE Division c	Year Impounded d	Use Type e	Chemical Type f	Sediment Type g	Drainage Area h	Surface Elevation i	Surface Area j	Volume k	Total Annual Discharge l	Storage Ratio m	Mean Depth n	Maximum Depth o	Outlet Depth p	Thermocline Depth q	Fluctuation r	Shoreline Length s	Shore Development t	Dissolved Solids u	Specific Conductance v	Growing Season w
Buckhorn	KY	ORD	1961	2	1	1	408	782	1,230	32	458	0.07	26	67	38	17	25	65	13.3	140	240	185
C. M. Harden	IN	ORD	1960	2	1	1	216	661	2,060	49	164	0.30	24	64	56	10	21	26	4.1	220	330	185
Cagles Mill	IN	ORD	1952	2	1	1	295	636	1,400	27	211	0.13	19	54	11	12	0	20	3.8	215	320	185
Center Hill	TN	ORD	1949	1	1	1	2,195	648	18,200	1,330	2,302	0.58	73	178	90	30	18	370	19.6	115	180	200
Charles Mill	OH	ORD	1936	2	1	1	215	997	1,350	7	135	0.06	5	15	5	+	10	33	6.4	300	430	160
Cheatham	TN	ORD	1956	1	1	1	14,160	385	7,450	103	16,380	0.01	14	45	23	+	4	320	25.0	120	180	200
Clendening	OH	ORD	1937	2	2	1	69	898	1,800	26	44	0.61	15	38	32	-	8	41	6.9	-	-	160
Cumberland	KY	ORD	1950	1	1	1	5,790	723	50,250	3,995	6,417	0.62	80	184	102	25	34	1,085	34.6	80	130	180
Dale Hollow	TN	ORD	1943	1	1	1	935	651	27,700	1,353	1,165	1.16	49	147	81	25	14	590	25.3	120	180	190
Deer Creek	OH	ORD	1968	2	1	2	277	810	1,277	21	165	0.13	16	40	38	-	25	19	3.8	395	550	167
Delaware	OH	ORD	1950	2	1	1	386	915	1,300	14	246	0.06	11	50	47	-	21	38	7.5	400	570	161
Dewey	KY	ORD	1950	2	2	1	206	645	1,100	17	164	0.11	16	53	5	15	30	52	11.2	60	100	180
Dillon	OH	ORD	1960	2	2	1	742	734	1,325	13	553	0.02	10	34	22	-	22	31	6.1	315	530	150
E. Br. Clarion River	PA	ORD	1952	2	2	1	72	1,658	1,020	52	97	0.54	51	135	106	25	40	20	4.5	85	125	120
East Lynn	WV	ORD	1972	2	2	1	138	662	1,005	-	94	-	-	-	-	-	-	-	-	-	-	190
Fishtrap	KY	ORD	1962	2	4	1	395	757	1,131	27	390	0.07	24	84	42	16	55	43	9.1	275	425	200
Grayson	KY	ORD	1968	2	2	1	196	645	1,500	29	145	0.20	40	45	40	-	15	74	13.6	120	195	185
Green River	KY	ORD	1969	2	1	1	682	675	8,210	224	812	0.28	27	83	70	15	11	81	6.4	85	130	190
Greenup	KY	ORD	1962	2	2	1	62,000	-	11,200	-	54,000	-	-	-	-	-	-	401	27.1	-	-	185
Huntington	IN	ORD	1969	2	1	1	707	749	900	13	443	0.03	14	34	19	15	12	38	9.0	360	535	155
J. Percy Priest	TN	ORD	1968	1	1	2	892	490	14,200	390	1,050	0.37	27	103	61	18	10	213	12.8	150	225	200
John W. Flannagan	VA	ORD	1965	2	4	1	221	1,396	1,143	67	192	0.35	59	186	160	40	50	39	8.2	200	300	180
Leesville	OH	ORD	1937	2	2	1	48	963	1,000	19	37	0.52	19	40	31	-	9	28	6.3	120	175	160
Michael J. Kirwan	OH	ORD	1967	2	2	2	81	982	2,450	48	70	0.68	20	54	25	25	10	20	2.9	250	390	150
Mississinewa	IN	ORD	1968	2	1	1	809	737	3,180	75	508	0.15	24	75	32	18	25	50	6.3	320	505	155
Monroe	IN	ORD	1966	2	1	1	441	538	10,750	182	345	0.53	17	56	16	21	0	130	9.0	95	140	185
Mosquito Creek	OH	ORD	1944	2	1	1	97	899	7,070	65	62	1.04	9	30	13	10	6	44	3.7	145	240	150
Nolin	KY	ORD	1963	2	1	1	702	515	5,790	170	642	0.27	29	103	31	18	25	172	16.1	180	245	190
Old Hickory	TN	ORD	1956	1	1	2	11,620	445	22,500	420	13,353	0.03	19	73	48	18	3	440	20.9	115	185	200
Piedmont	OH	ORD	1937	2	2	1	86	913	2,270	34	94	0.36	15	35	27	-	8	38	5.7	585	890	160
Pleasant Hill	OH	ORD	1938	2	1	1	197	1,020	850	14	137	0.10	16	50	44	-	4	13	3.2	215	345	149
Rough River	KY	ORD	1960	2	1	2	454	495	5,100	120	536	0.22	24	72	45	15	25	220	22.0	140	220	190
Salamonie	IN	ORD	1967	2	1	1	553	755	2,860	61	367	0.17	21	71	40	15	25	36	4.8	330	510	155
Senecaville	OH	ORD	1937	2	2	2	118	832	3,550	43	90	0.48	12	30	20	+	10	50	6.0	170	255	170
Shenango River	PA	ORD	1967	2	2	1	589	894	3,300	34	520	0.07	10	28	20	20	9	44	5.5	320	480	140
Summersville	WV	ORD	1965	2	1	1	803	1,650	2,723	186	1,357	0.14	68	270	155	20	130	60	8.2	40	55	150
Sutton	WV	ORD	1960	2	2	1	537	925	1,520	64	781	0.08	42	118	95	35	75	40	7.3	50	70	163

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Tappan	OH	ORD	1936	2	2	1	71	899	2,350	35	53	0.66	15	34	25	-	8	41	6.0	370	525	160
Tionesta	PA	ORD	1940	2	2	1	478	1,090	570	10	625	0.02	18	47	32	15	48	12	3.6	160	230	130
Tygart	WV	ORD	1938	2	2	1	1,184	1,088	1,650	101	1,787	0.06	61	128	88	115	73	31	6.7	55	75	150
Wills Creek	OH	ORD	1937	2	2	1	842	742	900	4	641	0.01	5	17	5	+	23	52	12.4	395	565	160
Winfield	WV	ORD	-	1	2	1	11,809	-	3,100	-	12,000	-	-	-	-	-	-	74	9.5	185	300	-
Youghiogheny River	PA	ORD	1943	2	2	1	434	1,430	2,620	130	620	0.21	50	117	103	30	55	38	5.3	50	70	130
									Upper Mississippi Drainage Area													
Ashtabula	ND	NCD	1949	2	1	1	7,470	1,266	5,430	71	84	0.84	13	50	28	+	6	65	6.3	385	500	122
Carlyle	IL	LMVD	1967	2	1	2	2,680	445	26,000	283	1,406	0.20	11	40	30	+	7	83	3.7	350	-	180
Coralville	IA	NCD	1959	2	1	2	3,115	480	4,900	53	1,100	0.05	11	30	18	+	25	68	6.9	315	475	162
Gull	MN	NCD	1912	2	1	1	287	1,196	13,139	71	76	0.94	5	6	0	+	1	32	2.0	250	450	133
Lac qui Parle	MN	NCD	1937	2	1	1	4,050	931	20,033	158	462	-	-	-	8	-	-	12	3.4	610	865	147
Leech	MN	NCD	1902	2	1	1	1,163	1,296	125,900	357	254	1.41	3	7	0	+	2	51	1.0	-	-	113
Pine River	MN	NCD	1886	2	1	1	562	1,231	13,810	98	154	0.64	7	13	0	+	2	36	2.2	-	-	110
Pokegama	MN	NCD	1889	2	1	1	3,265	1,274	15,880	61	825	0.07	4	9	0	+	2	30	1.7	-	-	104
Red Rock	IA	NCD	1969	2	1	2	12,323	725	8,950	90	3,375	0.03	10	53	31	-	29	65	4.9	415	700	170
Rend	IL	LMVD	1970	2	2	3	488	395	18,900	51	450	0.11	3	-	-	+	3	-	-	-	-	195
Sandy	MN	NCD	1911	2	1	1	421	1,218	9,060	53	150	0.35	9	11	0	+	2	21	1.6	-	-	116
Shelbyville	IL	LMVD	1970	2	1	2	1,030	600	11,100	210	570	0.37	19	67	45	30	20	250	16.9	375	-	181
Traverse	SD	NCD	1941	2	2	1	1,160	982	13,985	137	60	-	-	17	-	-	-	55	-	945	1,265	138
Winnibigoshish	MN	NCD	1884	2	1	1	1,442	1,300	69,160	568	370	1.53	8	12	0	+	2	40	1.1	-	-	129
									Lower Mississippi Drainage Area													
Arkabutla	MS	LMVD	1941	2	1	1	1,000	218	10,300	99	938	0.11	10	28	20	+	20	114	8.0	35	55	220
Enid	MS	LMVD	1952	2	1	1	560	243	11,900	173	605	0.29	15	67	33	+	25	125	8.2	40	60	224
Grenada	MS	LMVD	1954	2	1	1	1,320	208	25,610	335	1,271	0.26	13	62	30	+	27	148	6.6	40	60	231
Sardis	MS	LMVD	1940	2	1	1	1,545	250	22,500	336	1,607	0.21	15	71	22	+	30	110	5.2	35	50	217
Wappapello	MO	LMVD	1941	2	1	1	1,310	360	8,200	66	1,117	0.06	8	30	12	10	20	180	14.2	120	190	185
									Arkansas/White/Red Drainage Area													
Arkansas:																						
Blue Mountain	AR	SWD	1947	2	1	2	488	384	2,910	25	391	0.06	9	35	15	15	10	50	6.6	35	55	220
Canton	OK	SWD	1948	2	2	4	12,483	1,615	7,500	116	147	0.79	15	40	33	+	15	44	3.6	945	1,545	210
Conchas	NM	SWD	1939	2	2	1	7,409	4,201	9,600	330	712	0.46	34	76	45	40	30	96	7.0	470	740	180
Council Grove	KS	SWD	1964	2	1	3	246	1,270	2,860	38	92	0.41	13	50	39	+	1	37	5.0	205	345	183
Dardanelle	AR	SWD	1964	1	4	1	153,666	338	36,000	486	26,070	0.20	14	52	47	+	3	315	11.9	475	635	225

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Eufaula	OK	SWD	1963	1	4	1	47,522	585	102,500	2,329	3,964	0.59	23	87	80	22	15	600	13.4	255	440	220
Fall River	KS	SWD	1949	2	1	2	585	949	2,450	24	245	0.10	10	48	20	+	20	40	5.8	310	535	190
Fort Gibson	OK	SWD	1953	1	1	1	12,492	554	19,900	365	4,836	0.08	18	72	54	25	4	225	11.4	165	275	210
Fort Supply	OK	SWD	1942	2	2	4	1,735	2,004	1,880	14	49	0.29	7	17	10	+	15	26	4.3	650	960	200
Great Salt Plains	OK	SWD	1941	2	4	4	3,200	1,125	8,890	31	263	0.12	4	21	0	+	4	41	3.1	5,755	9,265	210
Heyburn	OK	SWD	1950	2	4	3	123	762	980	7	38	0.18	7	32	15	20	10	40	9.1	165	250	220
Hulah	OK	SWD	1951	2	1	2	732	733	3,600	35	255	0.14	10	48	22	+	15	62	7.4	300	495	200
John Redmond	KS	SWD	1964	2	1	3	3,015	1,036	7,780	54	1,209	0.04	7	23	3	+	0	50	4.1	290	480	183
Keystone	OK	SWD	1964	1	4	3	74,506	723	26,300	618	4,794	0.13	23	73	30	26	10	259	11.4	875	1,535	220
Marion	KS	SWD	1968	2	1	2	200	1,351	6,160	86	72	1.19	14	63	32	+	1	60	5.5	355	555	183
Nimrod	AR	SWD	1942	2	1	2	680	342	3,550	29	634	0.05	8	39	27	15	7	77	9.2	25	40	220
Oologah	OK	SWD	1972	2	1	1	4,339	638	29,500	553	1,866	0.30	19	70	48	25	20	209	8.7	265	425	210
Ozark	AR	SWD	1969	1	4	1	151,801	372	10,600	148	24,375	0.01	14	70	45	+	5	173	12.0	450	700	225
Robert S. Kerr	OK	SWD	1970	1	4	1	147,756	460	42,000	500	18,890	0.03	12	47	10	+	5	250	8.7	500	830	215
Tenkiller Ferry	OK	SWD	1953	1	1	1	1,610	630	12,500	629	1,119	0.56	50	140	125	30	7	130	8.3	100	180	205
Toronto	KS	SWD	1960	2	1	3	730	902	2,800	23	371	0.06	8	46	5	15	15	51	6.9	300	510	185
Webbers Falls	OK	SWD	1972	1	4	1	97,033	490	10,900	165	14,140	0.01	15	45	20	+	6	70	4.8	730	1,200	216
Wister	OK	SWD	1949	2	1	1	993	472	4,000	30	827	0.04	7	35	30	15	15	115	13.0	55	80	220
White:																						
Beaver	AR	SWD	1963	1	1	1	1,186	1,120	28,220	1,652	978	1.69	58	216	140	25	15	449	19.1	85	165	190
Bull Shoals	AR	SWD	1951	1	1	1	6,051	654	45,440	3,048	4,375	0.70	67	201	119	25	16	740	24.8	150	250	200
Clearwater	MO	SWD	1948	2	1	1	898	494	1,630	22	691	0.03	13	50	22	20	30	27	4.8	120	215	175
Greers Ferry	AR	SWD	1962	1	1	2	1,153	461	31,500	1,911	1,267	1.51	61	221	130	30	15	276	11.1	30	50	210
Norfork	AR	SWD	1943	1	1	1	1,808	552	22,000	1,251	1,339	0.93	57	177	105	28	18	380	18.3	175	310	200
Table Rock	MO	SWD	1958	1	1	1	4,020	915	43,100	2,702	2,561	1.06	63	220	140	25	30	745	25.6	130	180	185
Red:																						
Broken Bow	OK	SWD	1968	1	1	1	754	600	14,200	918	935	0.98	65	180	57	30	10	180	10.8	35	55	230
DeGray	AR	LMVD	1969	1	1	1	453	408	13,420	655	570	1.15	49	195	13	20	20	207	12.8	55	85	215
Greeson	AR	LMVD	1950	1	1	2	237	540	6,110	226	295	0.77	37	143	55	25	19	120	11.0	30	50	215
Lake O' The Pines	TX	LMVD	1957	2	4	2	850	229	19,780	255	580	0.44	13	30	28	-	5	144	7.3	135	240	240
Millwood	AR	SWD	1966	2	1	1	4,144	259	29,500	199	4,897	0.04	7	46	36	20	25	65	2.7	50	70	230
Ouachita	AR	LMVD	1952	1	1	1	1,105	572	36,740	1,920	1,078	1.78	52	200	80	25	13	690	25.7	40	70	220
Pat Mayse	TX	SWD	1967	2	1	2	175	451	5,993	120	112	1.07	20	44	0	25	1	67	6.2	90	135	183
Pine Creek	OK	SWD	1969	2	1	1	635	438	3,800	54	680	0.08	14	70	21	25	20	74	8.6	50	85	235
Texarkana	TX	LMVD	1956	2	4	1	3,443	220	34,225	145	-	-	4	25	10	+	17	165	6.4	330	525	235

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Texoma	TX	SWD	1944	1	4	1	39,719	617	89,000	2,733	3,446	0.79	31	115	95	+	10	580	13.9	790	1,405	230
Wallace	LA	LMVD	1946	2	4	1	266	142	2,300	7,800	-	-	3	32	0	+	-	30	4.5	-	-	270
Rio Grande and Gulf Drainage Area																						
Bardwell	TX	SWD	1965	2	1	3	178	421	3,570	43	55	0.78	12	43	25	+	3	25	3.0	190	330	243
Belton	TX	SWD	1954	2	1	3	3,560	594	12,300	373	400	0.93	30	124	110	35	3	136	8.8	240	360	242
Benbrook	TX	SWD	1952	2	1	3	429	694	3,769	88	40	2.18	23	75	65	+	10	24	2.8	175	260	265
Canyon	TX	SWD	1964	2	1	2	1,432	909	8,240	366	217	1.69	45	159	129	50	5	80	6.3	230	420	243
Grapevine	TX	SWD	1952	2	1	3	695	535	7,380	161	99	1.62	22	84	57	+	5	60	5.0	190	340	249
Hords Creek	TX	SWD	1948	2	4	3	48	1,900	510	6	1	4.66	11	52	40	+	7	11	3.5	440	750	235
Lavon	TX	SWD	1953	2	1	2	770	472	11,080	144	268	0.54	13	39	18	+	18	83	5.6	185	325	230
Lewisville	TX	SWD	1954	2	1	3	1,660	515	23,280	436	415	1.05	19	80	64	+	6	183	8.5	180	320	249
Navarro Mills	TX	SWD	1963	2	1	3	320	425	5,070	53	107	0.50	11	49	23	+	3	38	3.8	190	330	242
Proctor	TX	SWD	1963	2	4	3	1,265	1,162	4,610	31	89	0.35	7	42	33	+	4	38	4.0	440	750	242
Sam Rayburn	TX	SWD	1965	1	4	1	3,449	164	114,500	1,446	1,623	0.89	13	94	54	40	7	560	11.9	100	150	229
San Angelo	TX	SWD	1952	2	1	2	1,511	1,908	5,440	80	7	10.88	15	72	64	+	27	27	2.6	240	430	222
Somerville	TX	SWD	1967	2	2	2	1,012	238	11,460	144	180	0.80	13	38	27	+	1	85	5.7	230	420	250
Stillhouse Hollow	TX	SWD	1968	2	1	4	1,318	622	6,430	205	175	1.17	32	124	101	35	1	58	5.1	280	475	227
Waco	TX	SWD	1965	2	1	3	1,670	455	7,270	104	340	0.31	15	85	45	+	4	60	5.0	190	330	238
Whitney	TX	SWD	1952	1	4	3	26,170	522	16,700	411	1,156	0.36	25	97	33	+	7	190	10.5	1,200	2,100	230
Missouri Basin Drainage Area																						
Bowman-Haley	ND	MRD	1966	2	3	3	446	2,775	1,740	20	21	0.95	12	-	34	-	5	17	2.9	800	1,200	130
Cherry Creek	CO	MRD	1950	2	2	3	385	5,550	852	15	3	5.98	18	45	41	-	50	8	2.0	-	-	165
Fort Peck	MT	MRD	1937	1	2	1	57,500	2,246	215,000	17,930	6,876	2.61	83	196	126	40	10	1,520	23.4	400	600	125
Francis Case	SD	MRD	1953	1	2	1	263,500	1,365	104,028	4,834	17,290	0.28	46	138	57	+	35	575	12.7	440	-	150
Harlan County	NB	MRD	1952	2	1	2	20,752	1,946	13,468	350	254	1.38	26	70	67	+	13	58	3.6	310	490	160
Kanopolis	KS	MRD	1948	2	4	3	7,857	1,463	3,990	61	259	0.24	15	57	50	20	10	37	4.2	650	1,050	180
Lewis & Clark	SD	MRD	1955	1	2	1	279,500	1,208	31,300	477	18,670	0.03	15	48	25	+	4	100	4.0	450	750	162
Milford	KS	MRD	1967	2	1	3	24,880	1,144	16,000	415	656	0.63	26	74	54	-	7	163	9.2	350	560	177
Oahe	SD	MRD	1958	1	2	1	243,500	1,617	313,000	22,530	19,000	1.18	72	200	67	70	20	2,250	28.7	490	775	155
Perry	KS	MRD	1969	2	1	3	1,117	892	12,200	243	300	0.81	20	60	55	-	9	160	10.3	230	390	200
Pomona	KS	MRD	1963	2	1	3	322	974	4,000	71	129	0.55	18	59	7	-	9	52	5.9	265	430	182
Pomme de Terre	MO	MRD	1961	2	1	1	611	839	7,820	242	338	0.71	31	89	17	25	15	113	9.1	215	330	180
Rathbun	IA	MRD	1969	2	2	3	549	904	11,013	205	224	0.92	19	52	46	-	4	180	12.2	250	-	172
Sakakawea	ND	MRD	1953	1	1	1	181,400	1,850	324,000	22,640	20,000	1.13	70	178	61	-	10	1,340	16.8	450	765	119
Sharpe	SD	MRD	1963	1	2	1	259,300	1,420	56,090	1,725	14,375	0.12	31	75	20	+	2	200	6.0	440	700	145

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Stockton	MO	MRD	1970	1	1	2	1,160	867	24,900	912	710	1.28	37	109	50	25	5	250	11.3	225	-	180
Tuttle Creek	KS	MRD	1962	2	1	3	9,628	1,075	15,800	425	1,419	0.30	27	80	14	+	15	112	6.4	280	430	175
Wilson	KS	MRD	1965	2	4	3	1,917	1,516	9,000	246	38	6.39	27	80	41	30	6	100	7.5	1,510	2,565	171
North Pacific Drainage Area																						
Cottage Grove	OR	NPD	1942	2	1	1	104	790	1,135	32	203	0.16	28	71	67	+	40	9	2.3	45	70	161
Columbia Drainage Area																						
Blue River	OR	NPD	1968	2	1	1	88	1,350	940	83	345	0.24	88	248	218	35	170	-	-	50	75	165
Cougar	OR	NPD	1963	1	1	1	208	1,690	1,235	208	643	0.32	168	416	271	43	158	-	-	50	75	165
Detroit	OR	NPD	1953	1	1	1	438	1,564	3,455	436	1,692	0.26	126	364	167	27	114	38	4.6	40	65	165
Dexter	OR	NPD	1954	1	1	1	991	695	1,025	28	2,321	0.01	27	58	45	6	5	-	-	50	75	200
Dorena	OR	NPD	1949	2	1	1	265	832	1,815	72	546	0.13	40	97	93	30	62	12	2.0	45	70	160
Dworshak	ID	NPD	1973	1	-	1	-	-	16,970	-	-	-	-	-	-	-	-	-	-	-	-	159
Fall Creek	OR	NPD	1966	2	1	1	184	830	1,760	118	422	0.28	67	160	160	+	102	-	-	50	75	200
Fern Ridge	OR	NPD	1941	2	1	1	252	374	9,340	101	393	0.26	11	35	35	3	20	32	2.4	45	70	200
Foster	OR	NPD	1966	1	1	1	494	637	1,195	56	2,063	0.03	47	112	54	16	25	-	-	40	65	165
Green Peter	OR	NPD	1966	1	1	1	277	1,010	3,605	410	1,293	0.32	114	310	207	23	88	-	-	40	65	165
Hills Creek	OR	NPD	1961	1	1	1	389	1,541	2,710	350	828	0.42	129	296	157	40	93	35	4.8	70	105	165
Ice Harbor	WA	NPD	1962	1	1	1	109,000	440	9,200	-	36,000	-	-	-	-	-	-	56	-	-	-	185
Lookout Point	OR	NPD	1953	1	1	1	991	926	4,255	443	2,321	0.19	104	238	155	35	101	37	4.0	50	70	200
Lucky Peak	ID	NPD	1954	2	1	1	2,650	3,015	2,200	195	2,200	0.09	89	195	180	20	105	38	5.8	30	45	159
Pend Oreille	ID	NPD	1952	1	1	1	24,200	2,063	94,600	58,000	18,870	3.07	613	1,237	30	40	13	226	1.7	95	155	121
Rufous Woods	WA	NPD	1955	1	1	1	75,400	946	7,800	516	84,300	0.01	66	196	76	-	16	106	8.6	95	160	167
Central and South Pacific Drainage Area																						
Mendocino	CA	SPD	1958	2	1	2	105	738	1,690	70	260	0.27	41	114	95	20	35	15	2.6	95	145	200
Santa Margarita	CA	SPD	1941	2	1	2	112	1,295	690	22	13	1.62	31	75	71	-	9	5	1.4	300	465	280
Central Valley Drainage Area																						
Black Butte	CA	SPD	1963	2	1	1	736	450	2,845	74	481	0.15	26	75	63	-	40	25	3.4	211	325	250
Harry L. Englebright	CA	SPD	-	1	1	1	1,108	527	815	70	1,868	0.04	86	241	84	-	-	24	6.0	-	-	270
Isabella	CA	SPD	1954	2	1	1	2,074	2,555	4,800	150	650	0.23	30	90	78	+	20	28	2.9	150	230	160
New Hogan	CA	SPD	1963	2	1	1	362	685	2,650	223	176	1.27	84	150	140	-	40	24	3.3	-	-	220
Pine Flat	CA	SPD	1952	2	1	1	1,545	850	3,440	500	1,651	0.30	147	300	196	20	80	52	6.4	30	45	160

APPENDIX B: ESTIMATED ADJUSTED STANDING CROP OF FISH SPECIES GROUPS AS DETERMINED FROM COVE ROTENONE SAMPLING IN SUMMER FOR CORPS OF ENGINEERS RESERVOIRS, ARRANGED ALPHABETICALLY BY DRAINAGE AREAS

APPENDIX B

In the following tabulation, the standing crop estimates are all in pounds per acre and represent mean values if data for two or more years were available. Definitions of characteristics listed in the column headings are:

(a) Reservoir name - official name of the impoundment; "Lake" omitted from name when occurring as part of the official name.

(b) Number of years sampled - number of years that data were available.

(c) Mean year of samples - simple mean of the years for which data were available.

(d) Gars and bowfin - estimated standing crop of all species of gars (*Lepisosteus* spp.) and bowfin (*Amia calva*).

(e) Clupeids - estimated standing crop of Clupeidae (gizzard shad and threadfin shad [*Dorosoma* spp.] and herrings [*Alosa* spp.]).

(f) Carp - estimated standing crop of the carp, *Cyprinus carpio*.

(g) Minnows - estimated standing crop of all species of minnows (Cyprinidae, excluding the carp), all silversides (Atherinidae), all livebearers (Poeciliidae), and all killifishes (Cyprinodontidae).

(h) Catostomids - estimated standing crop of all suckers, carpsuckers, hog suckers, buffalofishes, and redhorses (Catostomidae).

(i) Catfishes - estimated standing crop of all bullheads, catfishes, and madtoms (Ictaluridae).

(j) Temperate basses - estimated standing crop of white perch, white bass, yellow bass, and striped bass (Percichthyidae).

(k) Sunfishes - estimated standing crop of all rock bass, fliers, redbreast sunfish, green sunfish, pumpkinseed, warmouth, orangespotted sunfish, bluegill, longear sunfish, and spotted sunfish (Centrarchidae).

(l) Black basses - estimated standing crop of all smallmouth bass, largemouth bass, redeye bass, and spotted bass (Centrarchidae).

(m) Crappie - estimated standing crop of all black crappie and white crappie (Centrarchidae).

(n) Freshwater drum - estimated standing crop of the freshwater drum, *Aplodinotus grunniens*.

(o) All other species - estimated standing crop of all trouts (Salmonidae), pikes (Esocidae), and perches (Percidae).

(p) Total - estimated standing crop for all fish species groups combined.

t = <0.05 lb/acre

Appendix B (Continued)

Reservoir Name a	No. of Years Sampled b	Mean Year of Samples c	Gars & Bowfin d	Clupeids e	Carp f	Minnows g	Catostomids h	Catfishes i	Temperate Basses j	Sunfishes k	Black Basses l	Crappie m	Freshwater Drum n	All Other Species o	Total p
Middle Atlantic Drainage Area															
John H. Kerr	11	1962	0.1	50.2	4.9	1.1	9.8	37.3	0.5	12.6	2.5	3.8		4.2	126.9
Gulf and South Atlantic Drainage Area															
Allatoona	9	1960	t	22.2	20.2	3.2	27.1	15.3	1.2	18.9	22.3	16.7		1.5	148.6
Clark Hill	11	1960	0.3	74.3	18.3	0.2	9.5	9.2	5.4	27.5	11.1	11.7		5.8	173.3
Hartwell	8	1965		38.3	21.5	2.3	1.8	5.6	0.5	28.7	10.9	20.7		7.3	137.6
Ocklawaha	2	1972	7.4	7.2		15.7		4.0		52.4	20.6	4.0		16.5	127.8
Okatibbee	4	1972	4.8	146.7	4.9	0.1	9.8	3.8		37.2	25.1	30.9		1.2	264.5
Seminole	4	1966	2.4	55.4	47.4	0.6	62.8	13.9	t	22.4	14.5	5.4		3.4	228.2
Sidney Lanier	7	1962		22.9	23.2	0.4	1.5	6.7	0.5	20.3	8.8	14.8		4.8	103.9
W. Kerr Scott	4	1966			54.3	0.1	17.9	3.5	0.2	13.9	10.0	3.1			103.0
Walter F. George	3	1965	1.3	99.9	10.4	1.8	4.2	23.1	1.2	25.0	10.9	3.5		2.2	183.5
Ohio Basin Drainage Area															
Barren River	5	1966	t	135.2	68.5	0.7	47.4	7.5	2.1	29.7	21.4	6.9		2.1	321.5
Buckhorn	4	1963	0.8	1.4		0.6	62.6	11.7	1.6	28.2	18.2	5.2	11.8	0.4	142.5
Center Hill	3	1960		69.0	12.8	0.6	6.4	7.4	1.4	10.8	7.5	4.8	20.2	0.1	141.0
Dale Hollow	6	1965	0.1	32.6	55.3	1.2	28.3	4.0	0.7	15.0	6.9	1.4	19.8	0.2	165.5
Dewey	15	1960		140.9	26.5	0.2	13.6	3.5	0.9	21.0	18.3	22.5		0.5	247.9
Fishtrap	1	1973		191.4	45.0	0.2	46.8	5.3	2.8	13.7	5.2	1.5		1.8	313.7
John W. Flannagan	3	1973				0.6	2.5	1.3		19.4	5.1				28.9
Cumberland	9	1958	1.0	77.4	15.1	0.5	45.2	11.6	2.1	8.7	10.9	15.0	17.8	9.8	215.1
Nolin	5	1966	0.1	176.3	107.2	4.7	13.8	21.1	0.7	22.9	25.7	18.4		0.4	391.3
Old Hickory	3	1960		152.9	68.0	0.4	244.8	6.2	0.5	27.5	9.6	9.2	30.2	2.7	552.0
Rough River	5	1964	0.5	122.1	11.4	0.6	82.2	30.2	1.9	41.3	29.7	14.8	2.7	0.8	338.2
Summersville	4	1970		1.9		2.9		2.0		28.3	22.2	1.9		1.8	61.0
Sutton	8	1967		1.9	10.2	2.5	73.6	12.7		8.4	20.6	15.2		1.9	146.4
Lower Mississippi Drainage Area															
Arkabutla	9	1964	14.5	44.5	2.0	3.6	88.4	36.7		2.6	4.2	26.5	21.8	0.4	245.2
Enid	16	1964	3.5	87.6	10.4	6.6	78.8	21.9	0.5	11.4	24.3	14.4	15.8	0.1	275.3
Grenada	17	1963	8.2	115.3	6.4	6.6	82.8	23.6	7.8	18.3	25.9	34.1	25.5	0.4	355.1
Sardis	16	1964	2.7	67.8	13.1	10.0	23.9	60.5	t	17.2	31.7	24.6	31.2	0.1	282.8
Wappapello	2	1955		130.5	44.8		314.2	11.8	0.5	29.6	20.8	10.6	113.6		676.4
Arkansas/White/Red Drainage Area															
Arkansas:															
Blue Mountain	5	1971	17.0	86.6	52.9		306.1	23.5	2.6	11.4	17.1	57.9	125.0	t	700.1
Canton	11	1968	0.6	73.4	70.0	1.9	54.8	20.9	75.3	7.7	12.0	25.5	47.7	0.5	390.3
Dardanelle	4	1972	4.1	150.5	73.6	0.1	641.9	38.4	1.6	17.4	33.4	23.4	95.4	0.1	1079.9

(Continued)

Appendix B (Concluded)

Reservoir Name a	No. of Years Sampled b	Mean Year of Samples c	Gars & Bowfin d	Clupeids e	Carp f	Minnows g	Catostomids h	Catfishes i	Temperate Basses j	Sunfishes k	Black Basses l	Crappie m	Freshwater Drum n	All Other Species o	Total p
Eufaula	2	1973	0.5	225.5	85.8	0.3	128.1	44.8	6.6	13.6	5.7	11.3	79.6	t	601.8
Fall River	1	1952	36.8	343.8	84.0		215.7	42.6		4.4	21.6	18.8	53.8	t	821.5
Fort Gibson	6	1958	0.5	147.5	64.5	t	158.0	25.4	5.2	20.4	16.2	17.3	110.9	0.1	566.0
Fort Supply	1	1952		187.5	137.6		62.2	79.0	0.9		22.6	5.0			494.8
Great Salt Plains	1	1973		54.9	44.5	2.8		0.3		0.4			16.6	3.1	122.6
Heyburn	3	1955	1.3	37.5	39.8		52.7	47.2		5.0	20.5	17.5	34.9	0.1	256.5
Hulah	1	1956		152.5	55.4		249.5	52.9	7.1	1.8	6.2	92.0	141.1		758.5
Keystone	4	1971	0.2	653.2	94.9	0.8	280.0	27.6	23.1	24.9	12.6	6.2	64.5	t	1188.0
Nimrod	5	1971	34.2	80.6	23.7	4.3	391.7	12.9	23.6	24.2	43.9	26.3	40.3	0.1	705.2
Oologah	1	1973		25.9	33.9	t	53.0	10.0	1.4	51.8	16.5	15.9	26.2	0.2	234.8
Ozark	4	1972	2.9	253.0	47.5	0.1	236.0	20.3	10.1	14.4	9.7	11.1	77.6	0.1	682.8
Robert S. Kerr	2	1972		151.9	57.6	0.7	144.2	9.1	0.9	49.6	26.8	35.5	21.5	t	497.8
Tenkiller Ferry	5	1966	0.1	180.9	2.2	2.8	91.2	10.1	0.2	30.0	11.8	9.6	27.2	0.3	366.4
Toronto	1	1971	0.6	5.1	78.3		90.8	7.5	0.5	2.3	0.8	13.8	47.0	t	246.7
Webbers Falls	1	1973	t	611.4	71.6	1.3	295.1	24.8	2.8	45.7	39.4	15.5	75.6	1.8	1185.0
Wister	4	1962	23.6	45.4	88.2	t	460.8	15.2	0.2	8.3	9.9	26.3	68.2		746.1
<u>White</u>:															
Beaver	13	1969	0.1	180.7	78.6	0.8	47.4	12.5	5.2	28.7	15.5	13.0	2.5	2.3	387.3
Bull Shoals	21	1963	0.9	125.3	17.6	2.1	48.5	15.7	11.1	40.0	17.7	4.2	21.8	1.8	307.1
Clearwater	1	1958		128.6	5.7		16.6	1.6		23.5	11.4	3.6			191.0
Greers Ferry	5	1971		30.5	10.2	t	167.8	10.4	4.0	7.1	29.1	0.6	4.0	2.0	265.7
Norfork	20	1962		102.7	3.4	4.9	60.4	24.1	9.7	23.5	15.6	13.0		3.2	260.5
Table Rock	2	1962		66.5	1.7		193.7	26.1		48.3	21.6	16.1		3.4	377.4
<u>Red</u>:															
Broken	1	1973		33.1		0.4	49.6	2.6		27.1	5.1	1.7		0.4	120.0
DeGray	5	1972	0.1	145.2	1.3	3.7	2.2	19.8	0.7	77.9	20.7	28.4		3.1	303.1
Greeson	6	1972	0.1	24.0		1.6	11.7	13.6	3.8	18.9	12.1	5.4		1.8	93.0
Millwood	2	1971	9.9	145.5	6.0	0.2	1.8	4.8	15.1	57.3	33.0	10.0	2.4	0.3	286.3
Ouachita	6	1966	3.0	44.7	0.2	1.6	39.7	10.1	0.2	27.3	15.1	4.1	17.5	0.2	163.7
Texoma	1	1973	1.0	334.4	148.5	0.6	9.2	11.2	1.2	37.0	61.8	4.8	75.3	3.3	688.3
							<u>Rio Grande and Gulf Drainage Area</u>								
Lavon	2	1955	1.6	70.8	88.7		0.3	17.9		15.8	8.6	46.6	2.4		252.7
							<u>Missouri Basin Drainage Area</u>								
Tuttle Creek	3	1970		252.4	46.4	0.6	263.0	14.6	14.2	5.4	3.8	17.6	42.5	0.6	661.1

APPENDIX C: SPORT AND COMMERCIAL FISH HARVEST

Appendix C: Part I

Annual Sport Fish Harvest for U. S. Reservoirs*

Drainage Area and Reservoir	Years Data	Reservoir Area, Acres	Total Sport Fish Harvest	Sport Fish Harvest in Pounds Per Acre: Carp	Catfishes	Temperate Basses	Sunfishes	Black Basses	Crappies	Walleye	Salmonids	Other Species
Central and South Pacific		4,950										
Cachuma, CA	1	3,100	10.5		0.4		5.2	1.6			3.3	
El Capitan, CA	2	500	78.2		31.2		26.2	4.4	16.3			
Piru, CA	1	500	94.0		5.0		71.0	6.0			12.0	
San Vicente, CA	3	850	20.3		0.4		14.9	4.3	0.7			
Central Valley		26,160										
Beardsley, CA	6	650	5.4								5.4	
Folsom, CA	1	9,500	5.7		1.0		0.9	3.4			0.4	
Ice House, CA	1	570	3.0								3.0	
Isabella, CA	2	4,800	125.4		1.8		30.7	12.9	76.8		3.2	
Millerton, CA	4	4,000	5.5				3.1	2.4				
Pine Flat, CA	1	5,970	21.8		0.1		11.8	4.3	4.6		0.1	
Spaulding, CA	1	670	1.0								1.0	
Columbia Basin		90,220										
Anderson Ranch, ID	4	4,780	5.2								1.6	3.6
Brownlee, ID-OR	1	30,000	3.4		2.1			0.8	0.6			
Cascade, ID	4	28,300	2.2		0.1						0.8	1.3
Henry's Lake, ID	3	6,000	7.4								7.4	
Palisades, ID	4	15,150	2.6								2.6	
Georgetown, MT	2	3,000	31.1								31.1	
Wildhorse, NV	1	1,830	26.0								26.0	
Cottage Grove, OR	1	1,160	20.1								20.1	
Great Basin		7,555										
Crowley, CA	1	4,800	33.4								33.4	
Adams-McGill, NV	2	625	3.4					3.4				
Deer Creek, UT	5	2,130	18.9								18.9	
Colorado Basin		334,456										
Apache, AZ	8	2,600	11.3	0.1	2.1		1.4	6.4	1.2			
Bartlett, AZ	6	2,768	16.1	0.1	1.4		1.2	11.2	2.2			
Big, AZ	1	570	110.0								110.0	
Canyon, AZ	8	900	18.1		1.5	0.6	5.6	10.2	0.1	0.1		
Mead, AZ-NV	2	115,000	5.1		0.8			3.8	0.3		0.1	0.1
Mohave, AZ-CA	4	26,100	4.9		0.1		0.1	1.8	0.1		2.7	
Pleasant, AZ	9	890	19.9	0.2	1.4	0.8	3.0	11.2	3.1			
Saguaro, AZ	6	1,260	18.0		0.9	1.0	6.6	9.3	0.1			
Granby, CO	2	5,900	13.2								13.2	
Navajo, NM	1	8,600	10.4				1.2	0.2			9.0	

* All reservoirs for which harvest data are currently available in the National Reservoir Research Program files are included. Mean harvest values were calculated if data for two or more years were available.

Appendix C: Part I (Continued)

Drainage Area and Reservoir	Years Data	Reservoir Area, Acres	Total Sport Fish Harvest	Sport Fish Harvest in Pounds Per Acre: Carp	Catfishes	Temperate Basses	Sunfishes	Black Basses	Crappies	Walleye	Salmonids	Other Species
Flaming Gorge, UT	8	25,000	19.4								19.4	
Powell, UT	2	128,000	2.4		0.2		0.1	1.5	0.4		0.1	
Scofield, UT	1	2,800	12.7								12.7	
Starvation, UT	1	3,310	84.3								84.3	
Steinaker, UT	2	658	26.3								26.3	
Strawberry, UT	4	6,900	19.0								19.0	
Upper Lake Mary, UT	4	600	21.5		0.5		7.8				12.8	0.4
Big Sandy, WY	1	2,600	8.7								8.7	
Missouri Basin		550,240										
Boyd, CO	4	1,670	5.1						1.8	2.2		1.1
Point of Rocks, CO	2	1,500	3.5								3.5	
Kanopolis, KS	6	3,550	30.5	13.9	3.3	6.4	0.1	0.4	4.0	1.8		1.5
Lake of the Ozarks, MO	6	59,700	12.1	0.2	1.3	2.7	0.4	0.7	6.3	0.1		0.1
Pomme de Terre, MO	6	7,820	18.3	2.6	0.1	0.6	0.4	3.2	11.8			0.1
Stockton, MO	1	24,900	25.0	7.2	4.4		2.1	10.0	0.6	0.3		0.8
Thomas Hill, MO	3	4,400	13.0	2.9	2.2			3.2	4.6			0.2
Ennis, MT	1	3,800	4.8								4.3	0.5
Ft. Peck, MT	1	212,000	0.1									0.1
Gibson, MT	1	1,360	1.1								1.1	
Hebgen, MT	1	12,670	1.3								1.3	
Pishkin, MT	1	1,000	0.8								0.8	
Willow Creek (Harrison), MT	1	860	13.0								13.0	
Willow Creek (Sun R.), MT	1	1,450	0.2								0.2	
Harry Strunk, NB	1	1,770	58.2	26.6	13.0		1.7	6.2	9.6	1.1		
Maloney, NB	2	1,550	20.6	2.5	1.6			0.1	13.8	2.0		0.4
Angostura, SD	2	4,830	14.0		0.2		0.9	0.2	0.2	1.4	2.2	5.5
Francis Case, SD	3	88,000	0.8	0.1			0.1	0.2	0.2			0.2
Sharpe, SD	1	55,800	2.9	0.1	0.1	0.1				1.9		0.7
Alcova, WY	2	2,250	16.6								16.6	
Boysen, WY	2	22,200	5.4						2.0	1.8		0.7
Buffalo Bill, WY	1	6,710	2.5								2.5	
Glendo, WY	1	7,800	36.9								36.9	
Ocean Lake, WY	4	6,150	12.7				0.2	0.6	11.2			0.8
Pathfinder, WY	2	4,500	10.4								10.4	
Seminoe, WY	1	12,000	2.6								2.6	
White River		138,230										
Beaver, AR	12	24,310	21.6	0.4	1.2	2.9	0.7	9.4	6.8	0.1		0.1
Bull Shoals, AR	12	45,440	27.7	0.1	4.8	5.7	0.9	9.2	6.4	0.3	0.2	0.1
Norfork, AR	1	22,000	19.7		4.2	9.0	0.5	4.7	1.0			
Clearwater, MO	4	1,650	35.2	1.7	4.4	0.6	3.4	4.4	20.6			
Table Rock, MO	12	43,100	26.8	0.3	1.2	1.8	2.2	12.5	8.6			
Taneycomo, MO	10	1,730	83.8	0.2	1.1	0.3	2.4	2.1	3.1	0.2	72.1	0.3

(Continued)

Appendix C: Part I (Continued)

Drainage Area and Reservoir	Years Data	Reservoir Area, Acres	Sport Fish Harvest in Pounds Per Acre: Total Sport Fish Harvest	Carp	Catfishes	Temperate Basses	Sunfishes	Black Basses	Crappies	Walleye	Salmonids	Other Species
Arkansas River		59,222										
Ft. Smith, AR	4	525	2.9		0.1		0.4	1.8	0.6			
Canton, OK	3	7,500	11.5	0.7	4.7	5.1			0.7	0.3		0.1
Eucha, OK	19	2,880	36.7		7.2	4.2	0.7	15.0	12.4			0.2
Ft. Gibson, OK	1	19,900	76.4	2.2	11.4	22.3	1.7	6.0	28.4			2.0
Spavinaw, OK	15	1,637	21.8	0.1	4.3	5.7	1.2	3.6	6.8			0.1
Tenkiller Ferry, OK	3	12,500	30.5	1.1	3.5	1.3	6.0	7.0	10.1			0.3
Bluewater, NM	1	550	92.2								92.2	
Conchas, NM	1	9,600	77.3	2.2	11.0		4.3	7.2	28.0	23.2		0.1
Ute, NM	1	4,130	23.9		6.7			2.0	14.8	0.4		
Red River		65,105										
Greeson, AR	2	6,110	8.6		0.8	2.1	0.2	4.1	1.4			
Bayou DeSiard, LA	2	1,215	30.0				14.8	4.4	9.6			1.2
Black Bayou, LA	?	3,960	50.4				34.4	6.3	9.3			0.4
Bussey Brake, LA	5	2,200	120.0				46.8	27.7	40.4			5.0
Caddo, LA	1	32,500	7.6			0.1	1.2	1.7	0.4			4.2
D'Arbonne, LA	2	14,670	75.2				19.4	18.8	34.6			2.5
LaFourche, LA	3	1,000	15.8				6.1	1.6	7.8			0.4
Cypress Springs, TX	1	3,450	49.9		5.2		15.3	9.7	17.6	1.5		0.6
Rio Grande and Gulf		46,356										
Storrie, NM	1	1,400	1.1						0.1		1.0	
Bastrop, TX	2	906	9.4	0.7	1.6		0.7	6.1	0.1			
Benbrook, TX	1	1,200	55.8	0.5	5.7		4.1	44.7	0.8			
Inks, TX	1	830	31.7	0.7	3.4	8.5	5.1	10.3	2.7			1.3
Medina, TX	2	5,570	27.7	2.8	4.0	3.3	4.4	8.0	5.2			
Nasworthy, TX	1	500	7.1	2.6	1.1	1.0	0.4	1.4	0.4			0.2
San Angelo, TX	1	4,000	7.9	0.2	2.0		1.3	1.2	2.9			
Sheldon, TX	3	1,200	28.5		2.0		11.2	15.0	0.3			
Spence, TX	1	14,950	11.0	0.1	1.2	2.2	0.1	5.6	1.8			
Whitney, TX	2	15,800	137.6	3.1	18.4	5.6	12.8	50.4	44.8			2.4
Lower Mississippi		77,500										
Enid, MS	12	13,000	4.5		0.1		0.1	0.5	3.9			
Grenada, MS	12	25,600	10.7		0.4		0.3	1.6	8.4			0.1
Sardis, MS	12	28,900	6.0		0.1		0.2	0.6	5.0			0.1
Duck Creek, MO	1	1,800	71.0		36.1		23.1	6.4	5.3			
Wappapello, MO	2	8,200	6.1	0.2	0.2	0.1	0.2	0.6	5.0			
Upper Mississippi		24,210										
Carlyle, IL	1	17,500	11.8	5.1	2.8		0.6	1.7	1.0			0.4

(Continued)

Appendix C: Part I (Continued)

Drainage Area and Reservoir	Years Data	Reservoir Area, Acres	Total Sport Fish Harvest	Sport Fish Harvest in Pounds Per Acre: Carp	Catfishes	Temperate Basses	Sunfishes	Black Basses	Crappies	Walleye	Salmonids	Other Species
Forbes, IL	1	525	18.1		3.5		11.0	3.2	0.3			
Spring, IL	2	1,285	20.8	8.0	5.3		2.8	1.7	2.0			0.8
Coralville, IA	1	4,900	13.3	7.1	6.0		0.1		0.1	0.1		
Tennessee Valley		296,210										
Wheeler, AL	1	67,100	3.5		0.3	0.1	0.7	0.7	1.6			0.1
Blue Ridge, GA	1	3,320	2.2		0.3		0.2	0.9	0.6	0.1		
Nottely, GA	1	3,850	4.2	0.3	1.6		0.5	1.1	0.6			
Kentucky, KY	4	158,300	10.6	0.5	2.7	1.7	0.4	1.0	3.2			1.1
Cherokee, TN	2	19,100	9.8	0.1	0.8	4.6	0.7	1.5	2.1			0.2
Norris, TN	1	34,200	21.0	0.5	1.5	2.5	0.9	6.0	5.8	2.6		1.1
Watauga, TN	5	6,430	13.0	0.6	0.7		0.8	3.2	3.1	3.9	0.8	0.2
Woods, TN	6	3,910	32.6	0.4	1.3		6.6	6.8	16.2	0.6		0.7
Ohio Basin		88,943										
Mermet, IL	1	690	33.2	0.4	1.1		23.6	2.8	4.0			1.2
Barren River, KY	4	10,050	6.7	0.6	0.2	0.5	0.4	2.7	2.2			
Beshear, KY	1	712	9.4		3.3		2.7	1.9	1.3			0.1
Buckhorn, KY	5	1,230	20.5		1.6	2.8	5.0	5.9	6.1	0.1		0.6
Dewey, KY	12	1,100	11.0	0.6	0.8	0.1	2.7	1.7	4.9			
Fishtrap, KY	2	1,131	4.4	0.6	0.1	0.1	0.5	0.9	2.2			
Herrington, KY	7	1,600	25.4		2.8	6.0	4.0	5.6	4.2			2.1
Malone, KY	2	690	30.0		13.7		14.0	2.3				
Nolin, KY	5	5,800	7.5	1.2	0.1		1.3	2.6	2.3			
Rough River, KY	4	4,860	11.7		1.1	0.7	3.1	4.2	2.7			
Deep Creek, MD	5	3,900	8.2		0.5		0.3	1.5	0.7	0.1		5.1
Buckeye, OH	3	3,140	16.2		4.1		2.9	1.2	3.0			5.1
Charles Mill, OH	3	1,350	5.0	2.2	0.9		0.6	0.5	0.8			
Loramie, OH	1	1,700	6.9		2.7		1.4	1.0	1.8			
Senecaville, OH	3	3,550	26.0	10.9			6.0	2.0	7.0			
Center Hill, TN	3	18,220	17.4		0.9		6.4	3.5	6.3			0.2
Dale Hollow, TN	8	27,700	8.9	0.1	0.7	1.0	1.0	2.8	2.9	0.4	0.2	0.1
Sutton, WV	2	1,520	28.8		1.4		7.0	18.6	0.8	0.4		0.2
South Atlantic - Gulf		105,110										
Jordan, AL	2	6,800	2.5	0.1		0.6		1.4	0.4			
Mitchell, AL	2	5,850	2.8	0.2		0.2	0.2	1.5	0.7			
Thollocco, AL	5	600	9.3		2.1		3.1	1.4	2.6			
Allatoona, GA	2	11,860	8.0		0.4	0.3	0.4	4.0	3.1			
Blackshear, GA	1	7,000	7.5		1.7	1.7	1.8	0.6	1.7			
Sidney Lanier, GA	2	38,000	2.4	0.4	0.4		0.2	0.8	0.5			
Bluff, MS	3	1,200	30.9		2.9		11.6	5.8	9.2			1.5

(Continued)

Appendix C: Part I (Concluded)

Drainage Area and Reservoir	Years Data	Reservoir Area, Acres	Total Sport Fish Harvest	Sport Fish Harvest in Pounds Per Acre: Carp	Catfishes	Temperate Basses	Sunfishes	Black Basses	Crappies	Walleye	Salmonids	Other Species
Okatibbee, MS	4	2,800	40.4		5.4		7.8	11.6	14.7			0.4
Ross Barnett, MS	10	31,000	26.0		1.9		4.9	8.1	10.7			0.3
South Atlantic - Atlantic		235,747										
Jackson, GA	4	4,750	36.6	0.2	4.2	0.5	4.2	6.6	20.8			0.2
Sinclair, GA	8	15,350	10.2		2.7	0.6	0.6	2.5	3.8			0.1
Badin, NC	2	5,973	9.0	0.6	0.5	1.2	1.4	2.1	1.6			
High Rock, NC	6	15,180	3.0	0.2	0.5	0.2	0.4		1.4			0.3
Tillery, NC	1	5,294	2.1			0.2	0.4	0.4	0.7			0.4
Clark Hill, SC-GA	4	71,500	2.1		0.1	0.4		1.0	0.6			
Greenwood, SC	3	10,500	15.3		1.5	1.1	1.1	4.5	6.8			0.2
Hartwell, SC-GA	1	56,400	9.3		0.2	1.0	0.7	3.0	3.9	0.3	0.3	
Murray, SC	2	50,800	10.2		0.4	2.0	0.5	3.8	3.0			0.4
Middle Atlantic		10,255										
Triadelphia, MD	2	790	13.0						13.0			
Round Valley, NJ	2	2,350	25.4		4.0	1.4	3.4	16.2	0.2		0.2	
Sprue Run, NJ	2	1,290	14.7		2.3		8.0	3.8			0.6	
Whitney Point, NY	1	1,200	28.6	17.4	2.1		1.6	4.3				3.2
Cohoon, VA	1	737	14.8				7.4	3.1	1.6			2.5
Meade, VA	1	512	23.5		0.1	0.1	15.8	5.6	0.8			0.8
Prince, VA	2	945	26.9		0.4	0.1	19.1	5.1				1.0
Smith-Whitehurst, VA	2	931	12.7		4.4		1.4	5.0	0.8			1.0
Western Branch, VA	1	1,500	7.9		0.1		7.1	0.5	0.1			0.1
New England		24,700										
Quabbin, MA	17	24,700	2.5		0.7	0.5	0.2	0.3			0.5	0.4
Great Lakes and St. Lawrence		16,610										
Carry Falls, NY	1	3,170	0.9		0.6			0.2	1.2			0.1
St. Mary's, OH	5	13,440	14.2	1.0	4.0		0.2	1.2	7.8			

AD-A044 550 ARMY ENGINEER WATERWAYS EXPERIMENT STATION VICKSBURG MISS F/G 5/3
THE DEVELOPMENT OF FISHERY COMPARTMENTS AND POPULATION RATE COE--ETC(U)
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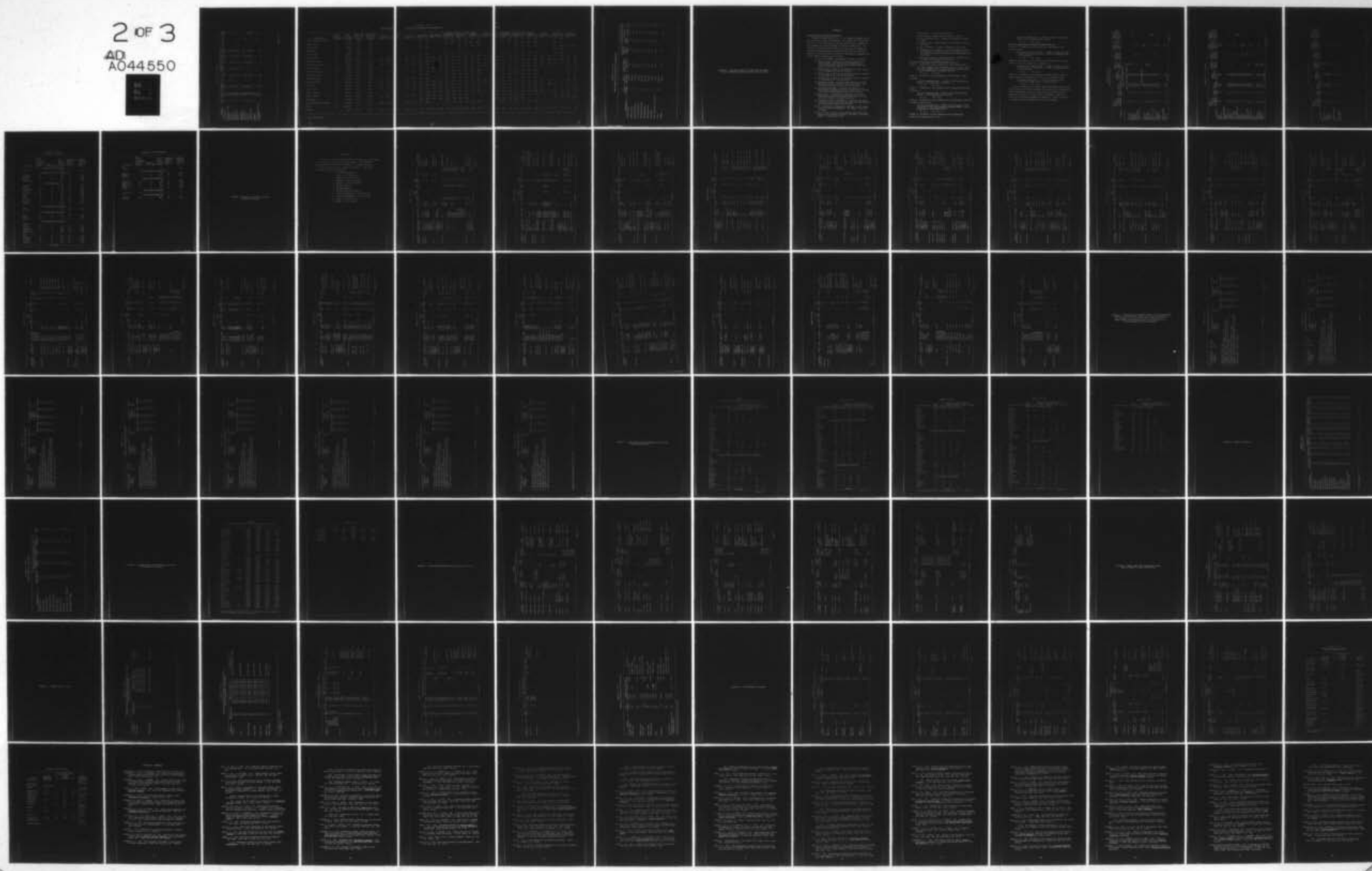

Appendix C: Part I (Concluded)

Drainage Area and Reservoir	Years Data	Reservoir Area, Acres	Sport Fish Harvest in Pounds Per Acre: Total Sport Fish Harvest	Carp	Catfishes	Temperate Basses	Sunfishes	Black Basses	Crappies	Walleye	Salmonids	Other Species
Okatibbee, MS	4	2,800	40.4		5.4		7.8	11.6	14.7			0.4
Ross Barnett, MS	10	31,000	26.0		1.9		4.9	8.1	10.7			0.3
South Atlantic - Atlantic		235,747										
Jackson, GA	4	4,750	36.6	0.2	4.2	0.5	4.2	6.6	20.8			0.2
Sinclair, GA	8	15,350	10.2		2.7	0.6	0.6	2.5	3.8			0.1
Badin, NC	2	5,973	9.0	0.6	0.5	1.2	1.4	2.1	1.6			
High Rock, NC	6	15,180	3.0	0.2	0.5	0.2	0.4		1.4			0.3
Tillery, NC	1	5,294	2.1			0.2	0.4	0.4	0.7			0.4
Clark Hill, SC-GA	4	71,500	2.1		0.1	0.4		1.0	0.6			
Greenwood, SC	3	10,500	15.3		1.5	1.1	1.1	4.5	6.8			0.2
Hartwell, SC-GA	1	56,400	9.3		0.2	1.0	0.7	3.0	3.9	0.3	0.3	
Murray, SC	2	50,800	10.2		0.4	2.0	0.5	3.8	3.0			0.4
Middle Atlantic		10,255										
Triadelphia, MD	2	790	13.0						13.0			
Round Valley, NJ	2	2,350	25.4		4.0	1.4	3.4	16.2	0.2		0.2	
Sprue Run, NJ	2	1,290	14.7		2.3		8.0	3.8			0.6	
Whitney Point, NY	1	1,200	28.6	17.4	2.1		1.6	4.3				3.2
Cohoon, VA	1	737	14.8				7.4	3.1	1.6			2.5
Meade, VA	1	512	23.5		0.1	0.1	15.8	5.6	0.8			0.8
Prince, VA	2	945	26.9		0.4	0.1	19.1	5.1				1.0
Smith-Whitehurst, VA	2	931	12.7		4.4		1.4	5.0	0.8			1.0
Western Branch, VA	1	1,500	7.9		0.1		7.1	0.5	0.1			0.1
New England		24,700										
Quabbin, MA	17	24,700	2.5		0.7	0.5	0.2	0.3			0.5	0.4
Great Lakes and St. Lawrence		16,610										
Carry Falls, NY	1	3,170	0.9		0.6			0.2	1.2			0.1
St. Mary's, OH	5	13,440	14.2	1.0	4.0		0.2	1.2	7.8			

App

Annual Sport F

Drainage Area	No. Reservoirs In Sample	Total Reservoir Area, acres	Simple Avg. Sport Fish Harvest	Area-Weighted Sport Fish Harvest	Carp lb/acre	Carp % TH*
Central and South Pacific	4	4,950	50.8	27.5		
Central Valley	7	26,160	24.0	31.1		
Columbia Basin	8	90,220	12.2	4.8		
Great Basin	3	7,555	18.6	26.8		
Colorado Basin	18	334,456	23.4	7.1		
Missouri Basin	26	550,240	12.0	5.1	0.6	11.8
White River Basin	6	138,230	35.8	25.9	0.2	0.8
Arkansas River Basin	9	59,222	41.5	51.0	1.4	2.7
Red River Basin	8	65,105	44.7	32.1		
Rio Grande and Gulf	10	46,356	31.8	57.5	1.5	2.6
Lower Mississippi	5	77,500	19.7	8.8		
Upper Mississippi	4	24,210	16.0	12.7	5.5	43.3
Tennessee Valley	8	296,210	12.1	10.3	0.4	3.9
Ohio Basin	18	88,943	15.4	12.4	0.7	5.6
South - Gulf	9	105,110	14.4	11.7	0.2	1.7
South - Atlantic	9	235,747	10.9	7.6		
Middle Atlantic	9	10,255	18.6	19.0	2.0	10.5
New England	1	24,700	2.5	2.5		
Great Lakes and St. Lawrence	2	16,610	7.6	11.7	0.8	6.8
Total	164	2,201,779				
Average		13,425	21.2	12.1	0.4	3.3

* TH = Total Harvest

Appendix C: Part II

Annual Sport Fish Harvest by Drainage Areas

ighted Fish est	Carp lb/acre	Carp % TH*	Catfishes lb/acre	Catfishes % TH	Temp. Basses lb/acre	Temp. Basses % TH	Sunfishes lb/acre	Sunfishes % TH	Black Basses lb/acre	Black Basses % TH	Crappies lb/acre	Crappies % TH	Walleye lb/acre	Walleye %
5			4.0	14.5			15.6	56.7	2.8	10.2	1.8	6.5		
1			0.7	2.2			9.1	29.3	4.9	15.8	15.1	48.6		
8			0.7	14.6					0.3	6.2	0.2	4.2		
8									0.3	1.1				
1			0.2	2.8			0.3	4.2	2.3	32.4	0.3	4.2		
1	0.6	11.8	0.4	7.8	0.4	7.8	0.2	3.9	0.7	13.7	1.2	23.5	0.3	5
9	0.2	0.8	2.9	11.2	4.4	17.0	1.2	4.6	9.4	36.3	6.4	24.7	0.2	0
.0	1.4	2.7	7.9	15.5	8[illegible]	[illegible]7.2	2.6	5.1	5.6	11.0	18.1	35.5	3.8	7
1			0.4	1.2	0.2	0.6	9.8	30.5	7.4	23.0	11.3	35.2	0.1	0
.5	1.5	2.6	7.6	13.2	3.2	5.6	5.5	9.6	21.9	38.1	16.8	29.2		
.8			1.0	11.4			0.7	8.0	1.0	11.4	5.9	67.0		
.7	5.5	43.3	3.6	28.3			0.8	6.3	1.4	11.0	0.8	6.3		
.3	0.4	3.9	1.8	17.5	1.5	14.6	0.6	5.8	1.7	16.5	3.2	31.1	0.4	[illegible]
.4	0.7	5.6	1.0	8.1	0.6	4.8	2.9	23.4	3.1	25.0	3.5	28.2	0.1	[illegible]
.7	0.2	1.7	1.0	8.5	0.2	1.7	2.0	17.1	3.7	31.6	4.4	37.6		
.6			0.5	6.6	0.9	11.8	0.5	6.6	2.4	31.6	2.9	38.2	0.1	
.0	2.0	10.5	1.9	10.0	0.3	1.6	6.2	32.6	6.2	32.6	1.4	7.4		
.5			0.7	28.0	0.5	20.0	0.2	8.0	0.3	12.0				
.7	0.8	6.8	3.4	29.0			0.2	1.7	1.0	8.5	6.5	55.6		
1	0.4	3.3	1.2	9.9	1.0	8.3	1.2	9.9	2.9	24.0	3.5	28.9	0.3	

Area-Weighted Harvest By Species Groups

Areas

	Area-Weighted Harvest By Species Groups												
ses	Sunfishes		Black Basses		Crappies		Walleye		Salmonids		Other Spp.	
% TH	lb/acre	% TH	lb/acre	% TH	lb/acre	% TH	lb/acre	% TH	lb/acre	% TH	lb/acre	% TH
	15.6	56.7	2.8	10.2	1.8	6.5			3.3	12.0		
	9.1	29.3	4.9	15.8	15.1	48.6			1.0	3.2		
			0.3	6.2	0.2	4.2			3.1	64.6	0.6	12.5
			0.3	1.1					26.5	98.9		
	0.3	4.2	2.3	32.4	0.3	4.2			3.9	54.9		
7.8	0.2	3.9	0.7	13.7	1.2	23.5	0.3	5.9	0.9	17.6	0.3	5.9
17.0	1.2	4.6	9.4	36.3	6.4	24.7	0.2	0.8	1.0	3.9	0.1	0.4
17.2	2.6	5.1	5.6	11.0	18.1	35.5	3.8	7.4	0.8	1.6	0.8	1.6
0.6	9.8	30.5	7.4	23.0	11.3	35.2	0.1	0.3			2.9	9.0
5.6	5.5	9.6	21.9	38.1	16.8	29.2					0.8	1.4
	0.7	8.0	1.0	11.4	5.9	67.0					0.1	1.1
	0.8	6.3	1.4	11.0	0.8	6.3					0.3	2.4
14.6	0.6	5.8	1.7	16.5	3.2	31.1	0.4	3.9			0.8	7.8
4.8	2.9	23.4	3.1	25.0	3.5	28.2	0.1	0.8	0.1	0.8	0.5	4.0
1.7	2.0	17.1	3.7	31.6	4.4	37.6					0.1	0.8
11.8	0.5	6.6	2.4	31.6	2.9	38.2	0.1	1.3	0.1	1.3	0.1	1.3
1.6	6.2	32.6	6.2	32.6	1.4	7.4			0.1	0.5	0.8	4.2
20.0	0.2	8.0	0.3	12.0					0.5	20.0	0.4	16.0
	0.2	1.7	1.0	8.5	6.5	55.6						
8.3	1.2	9.9	2.9	24.0	3.5	28.9	0.3	2.5	1.2	9.9	0.4	3.3

Appendix C: Part III

Annual Commercial Fish Harvest by Drainage Areas

Drainage Area	No. Reservoirs In Sample	Total Reservoir Area, acres	Simple Average Commercial Harvest, lb/acre	Area-Weighted Commercial Harvest lb/acre	Area-Weighted Harvest by Species Groups In Pounds Per Acre		
					Buffalo fishes	Catfishes	Carp
Colorado Basin	1	10,000	3.0	3.0	2.0	0.7	0.3
Missouri Basin	6	693,070	17.3	2.4	1.6	0.6	0.2
Upper Mississippi	2	17,200	20.0	29.1	18.9	7.3	2.9
Rio Grande and Gulf	4	63,730	4.0	3.2	2.1	0.8	0.3
Arkansas River Basin	14	113,397	6.4	4.2	2.7	1.1	0.4
Red River Basin	2	123,700	1.0	1.0	0.6	0.3	0.1
Tennessee Valley	12	520,210	11.9	14.6	9.5	3.6	1.5
Ohio Basin	4	55,370	8.5	3.5	2.3	0.8	0.4
Great Lakes and St. Lawrence	1	13,440	38.0	38.0	24.7	9.5	3.8
Total	46	1,610,117					
Average		35,002	10.2	7.0	4.5	1.8	0.7

APPENDIX D: PREDICTED STANDING CROP AND SPORT FISH HARVEST IN CORPS OF ENGINEERS RESERVOIRS GREATER THAN 500 ACRES

APPENDIX D

Multiple Regression Formula Description

Formulas are based on the U. S. customary system of measures and all data transformed to base 10 logarithms. The formulas were derived from data on U. S. reservoirs greater than 500 acres in area at normal pool. Fish standing crop formulas estimate uncorrected standing crop. All estimates are based on reservoir age at the mean year of standing crop or harvest samples and do not necessarily reflect current conditions. Definitions of various types of reservoirs represented in subsamples and of environmental variables are as follows:

(a) All = total sample, representing all types of reservoirs.

(b) Chemical type 1 - most of the dissolved solids in the reservoir water are composed of calcium-magnesium, carbonate-bicarbonate (see Rainwater (1962), Hydrologic Invest. Atlas HA-61, Plate 2).

(c) Chemical type 2 - most of the dissolved solids are composed of calcium-magnesium, sulfate-chloride.

(d) Chemical type 3 - most of the dissolved solids are composed of sodium-potassium, carbonate-bicarbonate.

(e) Chemical type 4 - most of the dissolved solids are composed of sodium-potassium, sulfate-chloride.

(f) Hydropower storage - reservoirs with hydroelectric power generation operation and with storage ratio greater than 0.165 (water exchange less than once in 60 days).

(g) Hydropower mainstream - reservoirs with hydroelectric power generation operation and with storage ratio less than 0.165 (water exchange greater than once in 60 days).

(h) Nonhydropower - reservoirs in sample that do not have hydroelectric generation function (flood control, irrigation, water supply, recreation reservoirs).

(i) "Selected" reservoirs (Formula E) - reservoirs less than 70,000 acres, with total dissolved solids less than 600 ppm, and growing season greater than 140 days.

(j) R^2 - coefficient of determination (portion of total variability explained by formula); N - the number of reservoirs in sample.

(k) Area - surface area in acres at average annual pool level when data are available; otherwise, use power, conservation, summer, or operating pool area.

(l) Mean depth - in feet, at listed area.

(m) Outlet depth - midline depth, in feet, of outlet.

(n) Total dissolved solids - residue on evaporation at 180°C, in ppm.

(o) Growing season - average number of days between first and last frost.

(p) Age of reservoir - in years, following closure of dam.

(q) Standing crop - estimated crop of fish in pounds per acre as determined by recovery of fishes from coves or open water areas enclosed by blockoff nets following application of rotenone.

(r) Sport fish harvest - estimated harvest of fishes by sport fishermen, in pounds per acre per year.

Reservoir fish Standing Crop Estimation Formulas (Part I)

Formula 2. Estimation of total standing crop - All reservoir types.

log (total standing crop in pounds per acre) = 1.6720 + 0.1776 log (outlet depth) + 0.6925 log (dissolved solids/mean depth) - 0.2458 (log(dissolved solids/mean depth))^2

$N = 173 \qquad R^2 = 0.51$

Formula 5. Estimation of total standing crop in hydropower storage reservoirs.

log (total standing crop) = - 0.6126 + 2.3658 log (dissolved solids) - 0.46 (log(dissolved solids))^2

$N = 44 \qquad R^2 = 0.74$

Formula 7. Estimation of total standing crop in hydropower mainstream reservoirs.

log (total standing crop) = 0.6150 + 2.2521 log (dissolved solids) - 0.3762 (log(dissolved solids))^2

$N = 52 \qquad R^2 = 0.70$

Formula 9. Estimation of total standing crop in nonhydropower reservoirs of chemical types 1 and 3.

log (total standing crop) = 1.2867 + 0.1275 log age + 0.1373 log (area) + 0.7027 log (dissolved solid/mean depth) - 0.2459 (log(dissolved solids/mean depth))^2

$N = 47 \qquad R^2 = 0.53$

Formula 10. Estimation of total standing crop in nonhydropower reservoirs of chemical types 2 and 4.

$$\log(\text{total standing crop}) = -0.9914 + 2.3317 \log(\text{dissolved solids}) - 0.417 (\log(\text{dissolved solids}))^2$$

$N = 30$ $\quad R^2 = 0.64$

Reservoir Angler Harvest Estimation Formulas (Part II)

Formula (D) Estimation of total annual sport fish harvest - All reservoir types.

$$\log(\text{total sport fish harvest}) = -0.8104 - 0.2266 \log(\text{area}) + 0.2090 \log(\text{dissolved solids}) + 1.1432 \log(\text{growing season}) - 0.2713 \log(\text{age})$$

$N = 103$ $\quad R^2 = 0.22$

Formula (E) Estimation of total annual sport fish harvest - selected reservoir types (see definition (i), page D3).

$$\log(\text{total sport fish harvest}) = -0.3892 - 0.1519 \log(\text{area}) + 0.2027 \log(\text{dissolved solids}) + 0.9796 \log(\text{growing season}) - 0.3055 \log(\text{age})$$

$N = 46$ $\quad R^2 = 0.69$

Formula (H) Estimation of annual sport fish harvest rate in terms of pounds harvested per angler-hour of effort - All reservoir types.

$$\log(\text{pounds/angler-hour}) = -0.7579 + 0.1187 \log(\text{area}) - 0.1036 \log(\text{storage ratio}) - 0.1285 \log(\text{age})$$

$N = 103$ $\quad R^2 = 0.13$

Harvest estimates for the Arkansas-White-Red Basins, Rio Grande and Gulf Drainage, North Pacific Drainage, and Central Valley Drainage were derived from Formula E if the reservoirs met the selection criteria. Formula E was found to yield more accurate estimates of harvest for reservoirs in the above drainages than Formula D. Formula D was used to estimate harvest in reservoirs in all other drainages.

Appendix D: Part I

Predicted Fish Standing Crop

Reservoir	Age of reservoir in years at the mean year of standing crop samples	Number of years sampled	Mean of standing crop samples	Formula 2 Estimate for all reservoir types	Formula 5 Estimate for hydropower storage reservoirs	Formula 7 Estimate for hydropower mainstream reservoirs	Formula 9 Estimate for nonhydropower reservoirs of chemical types 1 and 3	Formula 10 Estimate for nonhydropower reservoirs of chemical types 2 and 4
Middle Atlantic Drainage Area								
John H. Kerr	9	11	94.3	168	154			
Gulf and south Atlantic Drainage Area								
Allatoona	10	9	98.4	120	99			
Clark Hill	8	11	131.3	133	129			
Hartwell	4	8	105.6	78	76			
Ocklawaha	4	2	117.2	221				161
Okatibbee	4	4	204.0	178			145	
Seminole	9	4	145.4	192		134		
Sidney Lanier	5	7	74.0	128	138			
W. Kerr Scott	4	4	64.3	112			72	
Walter F. George	3	3	144.6	148		158		
Ohio Basin Drainage Area								
Barren River	2	5	220.1	214			181	
Buckhorn	2	4	85.2	213			135	
Center Hill	11	3	96.6	140	204			
Cumberland	8	9	134.8	107	167			
Dale Hollow	22	6	100.1	175	208			
Dewey	10	15	183.6	130				69
Fishtrap	11	1	221.6	262				164
John W. Flannagan	8	3	27.8	230				147
Nolin	4	5	280.5	214			190	
Old Hickory	4	3	300.4	230		268		
Rough River	5	5	228.3	225			190	
Summersville	5	4	54.2	77			47	
Sutton	7	8	74.3	119				58
Lower Mississippi								
Arkabutla	23	9	131.3	161			208	
Enid	12	16	166.9	156			172	

(Continued)

Reservoir	Age of reservoir in years at the mean year of standing crop samples	Number of years sampled	Mean of standing crop samples	Formula 2 Estimate for all reservoir types	Formula 5 Estimate for hydropower storage reservoirs	Formula 7 Estimate for hydropower mainstream reservoirs	Formula 9 Estimate for nonhydropower reservoirs of chemical types 1 and 3	Formula 10 Estimate for nonhydropower reservoirs of chemical types 2 and 4
Grenada	9	17	213.9	164			200	
Sardis	24	16	182.7	136			192	
Wappapello	14	2	328.4	218			284	
Arkansas/White/Red								
Arkansas:								
Blue Mountain	24	5	320.6	160			184	
Canton	20	11	210.0	247				180
Dardanelle	8	4	481.0	284		552		
Eufaula	9	2	355.2	292	261			
Fall River	3	1	500.0	245			204	
Fort Gibson	5	6	298.5	262		338		
Fort Supply	10	1	323.6	182				185
Great Salt Plains	32	1	81.3	26				76
Heyburn	5	3	141.9	234				134
Hulah	5	1	367.0	250			232	
Keystone	7	4	753.6	260		568		
Nimrod	29	5	336.4	162			175	
Oologah	1	1	150.7	276			241	
Ozark	3	4	379.3	282		515		
Robert S. Kerr	2	2	307.0	212		529		
Tenkiller Ferry	11	5	238.6	170	190			
Toronto	11	1	109.9	189			245	
Webbers Falls	1	1	755.3	235		561		
Wister	21	4	317.8	228			240	
White:								
Beaver	6	13	262.4	145	174			
Bull Shoals	12	21	207.0	179	228			
Clearwater	10	1	148.6	224			202	
Greers Ferry	9	5	128.1	65	76			
Norfork	19	20	173.8	204	240			
Table Rock	3	2	214.5	176	215			

(Continued)

Appendix D: Part I (Concluded)

Reservoir	Age of reservoir in years at the mean year of standing crop samples	Number of years sampled	Mean of standing crop samples	Formula 2 Estimate for all reservoir types	Formula 5 Estimate for hydropower storage reservoirs	Formula 7 Estimate for hydropower mainstream reservoirs	Formula 9 Estimate for nonhydropower reservoirs of chemical types 1 and 3	Formula 10 Estimate for nonhydropower reservoirs of chemical types 2 and 4
Red:								
Broken Bow	4	1	80.0	60	88			
DeGray	3	5	254.0	80	129			
Greeson	22	6	68.5	82	76			
Millwood	7	2	229.9	229			267	
Ouachita	14	6	105.6	85	99			
Texoma	29	1	477.8	324	240			
Rio Grande and Gulf								
Lavon	2	2	169.5	233			231	
Missouri Basin								
Tuttle Creek	8	3	362.5	212			273	

Appendix D: Part II

Predicted Sport Fish Harvest

Reservoir	Age of reservoir in years at the mean year of harvest samples	Number of years sampled	Mean of harvest samples in pounds per acre	Formula D or E Estimated harvest in pounds per acre	Formula H Estimated harvest in pounds per hour
Middle Atlantic Drainage Area					
Whitney Point	3	1	28.6	18	0.49
Gulf and South Atlantic Drainage Area					
Allatoona	15	2	8.0	9	0.43
Clark Hill	12	4	2.1	7	0.56
Hartwell	12	1	9.3	6	0.52
Okatibbee	5	4	40.4	17	0.44
Sidney Lanier	5	2	2.4	9	0.49
Ohio Basin Drainage Area					
Barren River	3	4	6.7	17	0.54
Buckhorn	3	5	20.5	26	0.47
Center Hill	3	3	17.4	15	0.53
Charles Mill	11	3	5.0	17	0.41
Cheatham	4	1	11.0	16	0.63
Dale Hollow	21	8	8.9	7	0.39
Dewey	12	12	11.0	15	0.36
Fishtrap	12	2	4.4	22	0.38
Nolin	4	5	7.5	18	0.37
Old Hickory	4	1	20.0	13	0.59
Rough River	4	4	11.7	18	0.45
Senecaville	10	3	26.0	13	0.37
Sutton	2	2	28.8	19	0.50
Upper Mississippi Drainage Area					
Carlyle	2	2	8.0	16	0.63
Coralville	6	1	13.3	16	0.52
Lower Mississippi Drainage Area					
Enid	13	12	4.5	10	0.43
Grenada	11	12	10.7	9	0.50
Sardis	25	12	6.0	7	0.45
Wappapello	10	2	6.1	11	0.51
Arkansas/White/Red Drainage Area					
Arkansas:					
Canton	20	3	11.5	17	0.35
Conchas	21	1	77.3	23	0.38
Fort Gibson	3	1	76.4	40	0.65
Keystone	8	1	24.6	18	0.56
Tenkiller Ferry	5	3	30.5	28	0.46
White:					
Beaver	6	12	21.6	21	0.45
Bull Shoals	11	12	27.7	19	0.48
Clearwater	10	4	35.2	27	0.45
Norfork	15	1	19.7	20	0.41
Table Rock	7	12	26.8	20	0.48

(Continued)

Appendix D: Part II (Concluded)

Reservoir	Age of reservoir in years at the mean year of harvest samples	Number of years sampled	Mean of harvest samples in pounds per acre	Formula D or E Estimated harvest in pounds per acre	Formula H Estimated harvest in pounds per hour
Red:					
Greeson	22	2	8.6	16	0.34
Rio Grande and Gulf Drainage Area					
Benbrook	3	1	55.8	61	0.38
San Angelo	3	1	7.9	50	0.34
Whitney	2	2	137.6	31	0.56
Missouri Basin Drainage Area					
Fort Peck	12	1	0.1	4	0.50
Francis Case	3	3	0.8	9	0.69
Kanopolis	10	6	30.5	19	0.40
Pomme de Terre	7	6	18.3	14	0.41
Sharpe	10	1	2.9	7	0.59
Stockton	1	1	25.0	18	0.57
North Pacific Drainage Area					
Cottage Grove	25	1	20.1	17	0.34
Central Valley Drainage Area					
Isabella	10	2	125.4	22	0.41
Pine Flat	11	1	21.8	22	0.41

APPENDIX E: VOLUMETRIC FOOD HABITS DATA FOR RESERVOIR FISH SPECIES

APPENDIX E

All values in the following tabulation are expressed as a percentage of total volume of food contents in the stomach. The parenthetical entries under the detritus food column are: 0 = organic detritus, I = inorganic detritus, and U = unspecified detritus. Superscript references indicate the following:

1 Includes photoplankton.
2 Frogs = 10% of the diet.
3 Tadpoles = 7.3% of the diet.
4 Tadpoles = 13.3% of the diet.
5 Tadpoles = 37.4% of the diet.
6 Includes detritus.
7 All phytoplankton.
8 Includes terrestrial insects.
9 Frogs and salamanders = 1.0% of the diet.
10 Frogs and salamanders = 3.0% of the diet.
11 Frogs = 1.4% of the diet.
12 Frogs = 9.1% of the diet.

Appendix E (Continued)

Fish Species	Location of Study	Age of Length	Season	Plant Material	Terrestrial Invertebrates	Zooplankton	Benthic Invertebrates	Fish	Detritus	Reference
Paddlefish	Mississippi River	Adult?	?	≤30		≤95	≤100			Forbes and Richardson (1920)
Spotted Gar	Tamiami Canal, FL	257-598 mm	Feb-Jun				23.7	76.3		Hunt (1952)
Longnose Gar	L. Mendota, WI	278 mm avg.	Aug-Sep					100		Pearse (1921)
	L. Mendota, WI L. Monona, WI L. Wingra, WI L. Waubesa, WI	180-652 mm (495 mm avg.)	Jul,Sep		1.0		10.3	88.8		Pearse (1916)
Bowfin	Statewide Illinois	?	Apr-Sep				67	33		Forbes and Richardson (1920)
	L. Mendota, WI L. Monona, WI L. Wingra, WI L. Waubesa, WI	383-465 mm (467 mm avg.)	Jul-Sep				9.4	90.1		Pearse (1916)
Gizzard Shad	L. Diversion, TX	Age I	Annual	12.7[1]		0.7	0.1		85.5(U)	Dalquest and Peters (1966)
			Annual	10.7[1]		2.8	0.1		86.5(U)	
			Annual	11.0[1]		2.3	1.3		86.2(U)	
	North Twin L., IA	24-82 mm		28.3[1]		10.7	t		61.0(U)	Kutkuhn (1958)
		53-115 mm		26.5[1]		5.9	1.6		66.0(U)	
		269-313 mm		12.9[1]		84.1	t		3.0(U)	
	L. Erie	24.5 mm	Summer	12.5		75.0			12.5(U)	Price (1963)
		49.0 mm		17.2		67.5	3.8		11.5(U)	
		73.5 mm		50.0		14.9	2.6		32.5(U)	
		98.0 mm		35.6		4.5	1.7		58.2(U)	
		122.5 mm		24.7		1.0	2.4		7.18(U)	
		147.0-193.5 mm		33.3			0.4		63.3(U)	
		196.0-242.5 mm				100.0				
		245.0-291.5 mm		2.5		96.3	1.2			
		294.0-365.0 mm				70.8	3.6		25.6(U)	
		367.5-438.5 mm				18.0			82.0(U)	
		Total Average		26.2		21.7	2.3		50.0(U)	
Threadfin Shad	L. Chicot, AR	36-119 mm	Feb-Nov	54.1[1]		6.8	39.1			Miller (1967)
	L. Havasu, CA & AZ	?	?	40[1]		52	8			Kimsey et al. (1957)
	Carl Pleasant, Saquaro, & Bartlett Lks., AZ	68-113 mm	Dec-Aug	23.6[1]		7.0	5.9		25.0(O); 38.4(I)	Haskell (1959)

(Continued)

Appendix E (Continued)

Fish Species	Location of Study	Age of Length	Season	Plant Material	Terrestrial Invertebrates	Zooplankton	Benthic Invertebrates	Fish	Detritus	Reference
Lake Whitefish	Pend Oreille L., ID	?	?	57			43			Jeppson and Platts (1959)
Mountain Whitefish	Cocolalla L., ID	?	?				100			Jeppson and Platts (1959)
	Pend Oreille L., ID	?	?	4			96			Jeppson and Platts (1959)
	Pyramid L., Alberta, Canada	61-228 mm	May-Sep		6	29	57			Rawson and Elsey (1948)
Kokanee Salmon	Elk L., OR	115-220 mm	Summer				100			Chapman et al. (1967)
Cutthroat Trout	Henry's L., ID	?	Jun-Sep			5.5	94.0	0.5		Irving (1954)
	Pend Oreille, Hayden, Cocolalla Lks., ID	100-198 mm	?				100			Jeppson and Platts (1959)
		198-294 mm	?	1			93	6		
		294-392 mm	?				100	t		
		392-490 mm	?				85	15		
Rainbow Trout	Paul L., British Columbia, Canada	<200 mm	May-Sep		8.2	48.8	43.0			Larkin and Smith (1953)
		200-240 mm	May-Sep		8.0	43.0	46.6	2.4		
		250-290 mm	May-Sep		4.0	33.2	52.2	10.6		
		300-340 mm	May-Sep		3.2	21.2	42.4	33.2		
		>350 mm	May-Sep		3.2	6.4	36.4	54.0		
	Elk L., OR	150-300+ mm	Summer				100			Chapman et al. (1967)
	Pend Oreille, Hayden, Cocolalla Lks., ID	100-198 mm	?				100			Jeppson and Platts (1959)
		198-294 mm	?	4			96			
		294-392 mm	?	2			76	22		
		392-490 mm	?	1			9	90		
		490 mm	?					100		
	L. Mendota, WI L. Monona, WI L. Wingra, WI L. Waubesa, WI	126.5 mm	Aug		10		90			Pearse (1916)
	Kootenay L., British Columbia, Canada	200-330 mm	?		67.6	0.4	1.3	28.1	2.6(0)	Larkin et al. (1956)
		330-460 mm	?		73.9		0.2	25.8	0.1(0)	
		460-910 mm	?		13.1		t	83.3	3.5(0)	
	Birch L., MI	187-294 mm	?	2	1	5	43	30	19(0)	Leonard and Leonard (1946)
		294-551 mm	?	6	3	t	24	48	19(0)	
	Pyramid L., Alberta, Canada	59-228 mm	May-Sep		12		73	10		Rawson and Elsey (1948)

(Continued)

Appendix E (Continued)

Fish Species	Location of Study	Age of Length	Season	Plant Material	Terrestrial Invertebrates	Zooplankton	Benthic Invertebrates	Fish	Detritus	Reference
Brook Trout	West Lost L., MI	123-306 mm	Jan-Dec			23.4	76.6			Momot (1965)
	Elk L., OR	100-300+ mm	Summer				100			Chapman et al. (1967)
	L. Mendota, WI L. Monoma, WI L. Wingra, WI L. Waubesa, WI	87-160 mm (103 mm avg.)	Aug	0.1	5.0		92.9			Pearse (1916)
	Pyramid L., Alberta, Canada	132-272 mm	May-Sep		5		87	8		Rawson and Elsey (1948)
Lake Trout	Pyramid L., Alberta, Canada	157-416 mm	May-Sep			2	91	7		Rawson and Elsey (1948)
Dolly Varden Trout	Pend Oreille, Hayden, Cocolalla Lks., ID	100-198 mm	?				100			Jeppson and Platts (1959)
		198-294 mm	?				100			
		294-392 mm	?	8			17	75		
		392-490 mm	?					100		
		>490 mm	?					100		
Central Mudminnow	Houghton L., MI	?	?	t		4.5	59.1	4.5		Hunt and Carbine (1950)
	L. Opinicon, Ontario, Canada	Adult: 62-78 mm	May-Oct				100			Keast and Webb (1966)
		Age I: 30-60 mm	May-Oct			20	80			
	L. Mendota, WI L. Monona, WI L. Wingra, WI L. Waubesa, WI	15.1-179 mm (42 mm avg.)	Apr-Aug	13.6	5.2	4.9	67.8		5.2(U)	Pearse (1916)
Northern Pike	Maple L., MN	412 mm	Summer					100		Seaburg and Moyle (1964)
	Grove L., MN	363 mm	Summer					90[2]		Seaburg and Moyle (1964)
	Houghton L., MI	11-20 mm	?			67.3	32.7			Hunt and Carbine (1950)
		21-40 mm	?	t		15.7	47.3	27.7[3]		
		41-80 mm	?	0.8		1.5	20.0	64.4[4]		
		81-152 mm	?	2.0			t	60.6[5]		
	Green L., WI	100-665 mm (445 mm avg.)	Aug-Sep	2			1	97		Pearse (1921)
	L. Mendota, WI	408 mm avg.	Aug-Sep	7				93		Pearse (1921)
	?	>313.6 mm	Jul-Aug					100		Reighard (1913)

(Continued)

Appendix E (Continued)

Fish Species	Location of Study	Age of Length	Season	Plant Material	Terres-trial Inverte-brates	Zoo-plankton	Benthic Inverte-brates	Fish	Detritus	Reference
Northern Pike(Cont.)	L. Mendota, WI L. Monona, WI L. Wingra, WI L. Waubesa, WI	45-876 mm (293 mm avg.)	May-Sep		0.1	2.6	14.9	84.0	1.2(U)	Pearse (1916)
Carp	L. Diversion, TX	>Age I	Annual	59.7		0.9	12.2		28.1(U)	Dalquest and Peters (1966)
			Annual	37.5		8.8	9.0		46.1(U)	
			Annual	42.3		4.1	5.0		46.1(U)	
	Lewis & Clark L., SD	Young-of-the-Year (20-99 mm)	Apr-Oct	3.0		27.0	19.0		51.0(O)	Walburg and Nelson (1966)
		Adult (100-619 mm)	Apr-Oct	10.0		10.0	19.0		61.0(O)	
	L. Carl Blackwell, OK	Young (<230 mm)	Dec-Nov	15.5		16.5	15.4		49.8(O); 2.8(I)	Summerfelt et al. (1971)
		Adult (>230 mm)	Dec-Nov	35.9		4.7	13.9	t	41.7(O); 3.8(I)	
	Grand L., OK	Adult	Dec-Nov	6.5		1.3	15.7		76.0(O); 0.5(I)	Summerfelt et al. (1971)
	L. Ft. Gibson, OK	Adult	Dec-Nov	20.1		0.7	22.9		55.3(O); 1.0(I)	Summerfelt et al. (1971)
	L. Eufaula, OK	Adult	Dec-Nov	25.2		0.5	11.0		62.1(O); 1.1(I)	Summerfelt et al. (1971)
	L. Texoma, OK	Adult	Dec-Nov	11.5		8.8	16.7		62.1(O); 1.0(I)	Summerfelt et al. (1971)
	Clear L., MN	>270 mm	Jun-Jul	30.0		17.0	38.0		33.0(U)	Scidmore and Woods (1960)
		<270 mm	Jun-Jul	42.0		40.0	18.0			
		392-515 mm	Jun-Jul	70.0		11.0	19.0			
		<245 mm	Jun-Jul			t	70.0		30.0(U)	
		245-490 mm	Jun-Jul						100.0(U)	
	Volney L., MN	>368 mm	Jun-Jul	44.0		t	12.0		44.0(U)	Scidmore and Woods (1960)
		>490 mm	Jun-Jul	18.0		60.0	12.0		10.0(U)	
		123-245 mm	Jun-Jul				90.0		10.0(U)	
		245-490 mm	Jun-Jul	40.0			10.0		30.0(U)	
		>490 mm	Jun-Jul	60.0			13.0		27.0(U)	
	Beaver L., MN	270-368 mm	Jun-Jul	20.0		t	49.0		23.0(O); 8.0(I)	Scidmore and Woods (1960)
		>392 mm	Jun-Jul	60.0		t	14.0		25.0(O); 1.0(I)	

(Continued)

Appendix E (Continued)

Fish Species	Location of Study	Age of Length	Season	Plant Material	Terrestrial Invertebrates	Zooplankton	Benthic Invertebrates	Fish	Detritus	Reference
Carp (Cont.)	Beaver L., MN(Cont.)	>392 mm	Jun-Jul	13.0		27.0	57.0		3.0(I)	
		>392 mm	Jun-Jul			17.0	8.0		75.0(O)	
	Green L., WI	133 mm	Sep	3.0		11.0	74.0		10.0(O); 2.0(I)	Pearse (1921)
	L. Mendota, WI	366 mm avg.	Aug-Sep	2.8			34.2	35.0	27.9(O)	Pearse (1921)
	L. Mendota, WI L. Monona, WI L. Wingra, WI L. Waubesa, WI	15-460 mm (42 mm avg.)	Apr,Jul-Sep	5.7	2.9	14.0	73.5		1.5(U)	Pearse (1916)
	Broad L., IL	Adult?	?	67[6]			33			Garmon (1888)
	L. Keowee, SC	?	Annual	2-18.7, $\bar{x}$=7		3-8, $\bar{x}$=5	7-25.5, $\bar{x}$=15		56.8-74.4(O), $\bar{x}$=65; 2.5-6.1(I)	Cherry and Guthrie (1975)
Northern Squawfish	Pend Oreille, Hayden, Cocolalla Lks., ID	100-198 mm	?				50	50		Jeppson and Platts (1959)
		198-294 mm	?	3			79	18		
		294-392 mm	?	2			4	94		
		392-490 mm	?	7			7	86		
		>490 mm	?					100		
Creek Chub	Houghton L., MI	?	?	14.4			7.9	77.6		Hunt and Carbine (1950)
Peamouth	Pend Oreille L., ID	?	?	9			91			Jeppson and Platts (1959)
Common Shiner	Houghton L., MI	?	?	16.7			83.3			Hunt and Carbine (1950)
	?	85.8 mm	?	t		67	33			Reighard (1913)
	?	?	?	35	5		60	t		Forbes and Richardson (1920)
Golden Shiner	Houghton L., MI	?	?	30.8		57.7	11.5			Hunt and Carbine (1950)
	L. Opinicon, Ontario Canada	115-137 mm	May-Oct	t	20	20-90	10-30			Keast and Webb (1966)
	L. Mendota, WI	96 mm avg.	Aug-Sep	25			75			Pearse (1921)
	L. Mendota, WI L. Monona, WI L. Wingra, WI L. Waubesa, WI	23.5-152 mm (68 mm avg.)	Apr,Aug	4.5	0.1	74.1	16.2		2.2(U)	Pearse (1916)

(Continued)

Fish Species	Location of Study	Age of Length	Season	Plant Material	Terrestrial Invertebrates	Zooplankton	Benthic Invertebrates	Fish	Detritus	Reference
Blackchin Shiner	L. Houghton, MI	?	?	t		4.4	81.5	14.1		Hunt and Carbine (1950)
	L. Mendota, WI	58 mm avg.	Aug-Sep	0.8			99.2			Pearse (1921)
	L. Opinicon, Ontario Canada	40-70 mm	May-Aug	6.5		54.5	39.0			Keast (1965)
	L. Mendota, WI L. Monona, WI L. Wingra, WI L. Waubesa, WI	16.8-54 mm (34 mm avg.)	Apr-Aug	15.6	9.1	44.4	24.0		4.1(O) 2.4(I)	Pearse (1916)
Steelcolor Shiner	?	?	?	33	33		34	t		Forbes and Richardson (1920)
Spottail Shiner	Douglas L., MI	Immature	?			100				Reighard (1913)
	Houghton L., MI	?	?	23.1		46.2	30.7			Hunt and Carbine (1950)
Blacknose Shiner	Houghton L., MI	?	?	16.0		48.0	36.0			Hunt and Carbine (1950)
Rosyface Shiner	Houghton L., MI	?	?			4.7	95.3			Hunt and Carbine (1950)
Mimic Shiner	Houghton L., MI	?	?	30.4		16.0	36.9			Hunt and Carbine (1950)
Spottail Shiner	Lake Erie	24.5 mm	Summer			8.7	47.8		43.5(U)	Price (1963)
		49.0 mm		0.1		7.2	27.6		65.1(U)	
		73.5 mm				11.9	57.4		30.7(U)	
		98.0-144.5 mm				7.8	63.4	t	28.7(U)	
		147.0-193.5 mm					100.0			
		Total Avg.		t		8.6	60.1	t	31.3(U)	
Redbelly Dace	Houghton L., MI	?	?	78.8		t	21.2			Hunt and Carbine (1950)
Bluntnose Minnow	L. Opinicon, Ontario, Canada	50-75 mm	May-Sep	2.0	1.6	38.2	15.8		42.4(O)	Keast (1965)
	Houghton L., MI	?	?	97.0		t	2.2			Hunt and Carbine (1950)
	L. Mendota, WI	46 [illegible] avg.	Aug-Sep	24.3		45.5	26.9		4.3(O)	Pearse (1921)
	L. Mendota, WI L. Monona, WI L. Wingra, WI L. Waubesa, WI	23.[illegible] 0 mm (40 mm avg.)	Jun-Aug Nov-Dec	20.2	4.5	27.7	27.6		20.0(U)	Pearse (1916)
Brassy Minnow	Houghton L., MI	?	?	100						Hunt and Carbine (1950)

(Continued)

Appendix E (Continued)

Fish Species	Location of Study	Age of Length	Season	Plant Material	Terres-trial Inverte-brates	Zoo-plankton	Benthic Inverte-brates	Fish	Detritus	Reference
Suckermouth Minnow	?	?	?				100			Forbes and Richardson (1920)
Flathead Minnow	L. Mendota, WI L. Monona, WI L. Wingra, WI L. Waubesa, WI	45-51 mm (49 mm avg.)	Sep	1.3		2.6	87.2		8.3(U)	Pearse (1916)
River Carpsucker	L. Diversion, TX	>Age I	Annual	10.5	t	16.0	5.6		72.0(U)	Dalquest and Peters (1966)
			Annual	4.0	t	14.6	5.6		75.8(U)	
			Annual	2.8	t	7.0	5.8		84.4(U)	
	Lewis & Clark L., SD	Young-of-the-Year (30-65 mm)	Apr-Oct	t	t	2	5		87(O); 6(I)	Walberg and Nelson (1966)
		$\geq$Age I (65-368 mm)	Apr-Oct	3	t	15	3		67(O); 12(I)	
	Grand L., OK	Adult	Sep-Aug	0.1		4.3	20.5		75.0(O); 0.1(I)	Summerfelt et al. (1972)
	L. Ft. Gibson, OK	Adult	Sep-Aug	45.3		9.9	1.5		43.1(O); 0.2(I)	Summerfelt et al. (1972)
	L. Eufaula, OK	Adult	Sep-Aug			2.0	1.5		96.5(O)	Summerfelt et al. (1972)
	L. Texoma, OK	Adult	Sep-Aug	t		10.6	1.1		87.8(O); 0.8(I)	Summerfelt et al. (1972)
White Sucker	Clear L., MN	<245 mm	Jun-Jul			t	50		50(U)	Scidmore and Woods (1960)
		245-490 mm	Jun-Jul				80		20(U)	
	L. Mendota, WI L. Monona, WI L. Wingra, WI L. Waubesa, WI	13-60 mm (29 mm avg.)	Jul-Aug	3.0	0.4	18.4	73.1		3.6(U)	Pearse (1916)
	Douglas L., MI	42.9-49.0 mm	Sep			100				Reighard (1913)
	L. Mendota, WI	304 mm avg.	Aug-Sep	20.0		1.7	66.6		11.7(O)	Pearse (1921)
	Green L., WI	364-542 mm (445 mm avg.)	Aug			0.7	90.6		8.7(I)	Pearse (1921)
Longnose Sucker	Yellowstone L., WY	Adults	Summer	18.7			65.6		15.7(U)	Brown and Graham (1953)
	Pyramid L., Alberta, Canada	49 mm	May-Sep			70	30			Rawson and Elsey (1948)
		49 mm				2	98			

(Continued)

Appendix E (Continued)

Fish Species	Location of Study	Age of Length	Season	Plant Material	Terrestrial Invertebrates	Zooplankton	Benthic Invertebrates	Fish	Detritus	Reference
Northern Hogsucker	?	?	?				100			Forbes and Richardson (1920)
Smallmouth Buffalo	L. Diversion, TX	Age I	Annual Annual Annual	10.1 2.4 1.6		43.0 55.7 61.8	30.7 31.9 24.7		16.6(U) 9.8(U) 11.8(U)	Dalquest and Peters (1966)
	Lewis & Clark L., SD	Young-of-the-Year (35-64 mm)	Jun-Oct Apr-Jun			99			1(I)	McComish (1967)
		Subadult and Adult (250-400 mm)	Jun-Oct Apr-Jun	13	t	32	6		49(O); 2(I)	
	Grand L., OK	Adult	Oct-Aug	1.0		13.7	1.0		85.3(O)	Tafanelli et al. (1971)
	L. Ft. Gibson, OK	Adult	Oct-Aug	t		12.8	4.1		83.1(O); 0.3(I)	Tafanelli et al. (1971)
	L. Texoma, OK	Adult	Oct-Aug	t		17.5	0.9		81.2(O); 0.2(I)	Tafanelli et al. (1971)
	Apache L., AR	Adults	Jan-Dec	6.4[1]		5.4	42.1		25.3(O); 20.6(I)	Minckley et al. (1970)
	Mississippi & Illinois R.	?	Apr-Oct	20 30		25 20	55 50			Forbes and Richardson (1920)
Bigmouth Buffalo	Lewis & Clark L., SD	Young-of-Year (16-47 mm)	Jun-Aug			100				McComish (1967)
		Subadult and Adult (330-530 mm)	Jun-Oct May-Sep	1		98			2(I)	
	Grand L., OK	Adult	Oct-Aug			6.7	1.1		92.3(O)	Tafanelli et al. (1971)
	L. Eufaula, OK	Adult	Oct-Aug			38.9	0.1		60.6	Tafanelli et al. (1971)
	L. Texoma, OK	Adult	Oct-Aug			19.9	0.2		79.3(O); 0.1(I)	Tafanelli et al. (1971)
	L. Poinsett, SD	Fry (12.5-21.0 mm)	Jun			25.0	75.0			Starostka and Applegate (1970)
		Subadult and Adult (236-833 mm)	Jan-Nov	10.3[7]		88.5	1.2			

(Continued)

Fish Species	Location of Study	Age of Length	Season	Plant Material	Terrestrial Invertebrates	Zooplankton	Benthic Invertebrates	Fish	Detritus	Reference
Bigmouth Buffalo (Cont.)	Clear L., MN	Adults	Jun	t		70	4		13(O); 13(I)	Scidmore and Woods (1960)
	Pasqua L., Saskatchewan, Canada	Young-of-the-Year (13-46 mm)	Summer 55	4.4[7]		74.3	21.3			Johnson (1963)
			Summer 56			87.7	12.3			
		Juvenile and Adult (267-727 mm)	May-Aug	1.1[7]		63.6	35.3			
	Echo L., Saskatchewan, Canada	Juvenile and Adult (267-727 mm)	May-Aug	0.9[7]		72.8	26.3			Johnson (1963)
	Illinois-Statewide	?	?	33		33	33			Forbes and Richardson (1920)
	Roosevelt L., AZ	Adults	Jan-Dec	4.8[1]		61.6	0.1		25.7(O); 7.8(I)	Minckley et al. (1970)
	Apache L., AZ	Adults	Jan-Oct	35.8[1]		33.9	1.0		24.4(O); 5.8(I)	Minckley et al. (1970)
Black Buffalo	Apache L., AZ	Adults	Jan-Dec	3.0[1]		6.0	51.0		30.0(O); 10.3(I)	Minckley et al. (1970)
	Illinois-Statewide	?	?	33		13	54			Forbes and Richardson (1920)
Black Redhorse	?	?	?				100			Forbes and Richardson (1920)
Black Bullhead	Mitchell L., MI	Age 0 (10-60 mm)	Summer			43.7	56.3			Williams (1970)
	Maple L., MN	198-216 mm	Summer	13		30	53	4		Seaburg and Moyle (1964)
	Cedar Creek, WI	40-60 mm	Sep	3.4			81.5		15.1(O)	Darnell and Meierotto (1961)
	L. Mendota, WI L. Monona, WI L. Wingra, WI L. Waubesa, WI	35-280 mm (119 mm avg.)	Aug-Sep	7.3	5.1	4.2	76.0		6.3(U)	Pearse (1916)
	L. Poinsett, SD	Young-of-the-Year	Aug-Sep			94.4	5.6			Repsys et al. (1976)
		143-304 mm	Mar-Nov	1.7		32.2	38.9	27.2		

(Continued)

Appendix E (Continued)

Fish Species	Location of Study	Age of Length	Season	Plant Material	Terrestrial Invertebrates	Zooplankton	Benthic Invertebrates	Fish	Detritus	Reference
Yellow Bullhead	Green L., WI	270, 290 mm	Aug	10.0		0.1	57.4	32.5		Pearse (1921)
	L. Mendota, WI	221 mm avg.	Aug-Sep	10.1		3.3	85.3		1.3(O)	Pearse (1921)
Brown Bullhead	L. Opinicon, Ontario, Canada	30-60 mm	May-Sep			60	40			Keast and Webb (1966)
		120-130 mm	May-Sep				100			
	Cocolalla L., ID	?	?	3			26	71		Jeppson and Platts (1959)
	Hayden L., ID	?	?	38			19	43		Jeppson and Platts (1959)
	Green L., WI	265-320 mm (302 mm avg.)	Aug	22.8		0.1	71.5		5.6(U)	Pearse (1921)
	L. Mendota, WI	131 mm avg.	Aug-Sep	27.7		3.4	70.9		1.4(O); 0.6(I)	Pearse (1921)
	L. Mendota, WI L. Monona, WI L. Wingra, WI L. Waubesa, WI	25-94 mm (46 mm avg.)	May-Jun, Aug	0.9	2.2	41.5	53.2		2.3(U)	Pearse (1916)
Flat Bullhead	L. Keowee, SC	?	Annual	3-35, $\bar{x}$=10			12-65, $\bar{x}$=32	0-12 $\bar{x}$=3	12-38, $\bar{x}$=27(O); 6-42, $\bar{x}$=15(I)	Cherry and Guthrie (1975)
Blue Catfish	Ohio R., KY	105-172 mm	Mar-May				31.3	9.8	58.9(O)	Minckley (1961)
Channel Catfish	Des Moines R., IA	<98 mm 98-194 mm 194-294 mm >294 mm	Apr-Oct Apr-Oct Apr-Oct Apr-Oct	1 11 23 19			98 81 65 47	1 8 12 35		Bailey and Harrison (1945)
	Reelfoot L., TN	?	?	28			65	7		McCormick (1940)
	Illinois and Mississippi R.	?	Spring-Autumn	25			60	15		Forbes and Richardson (1920)
	L. Erie	24.5-46.5 mm 49.0-71.0 mm 73.5-95.5 mm 98.0-144.5 mm 147.0-193.5 mm	Summer			 3.5 26.4 3.5 18.0	100 91.3 65.1 86.9 68.9	 0.7 0.2	 5.2(U) 8.5(U) 8.9(U) 12.9(U)	Price (1963)

(Continued)

Fish Species	Location of Study	Age of Length	Season	Plant Material	Terrestrial Invertebrates	Zooplankton	Benthic Invertebrates	Fish	Detritus	Reference
Channel Catfish (Cont.)	L. Erie (Cont.)	196.0-242.5 mm		t		23.0	61.7	1.9	13.4(U)	
		245.0-291.5 mm		t		7.4	76.1	2.4	14.1(U)	
		294.0-365.0 mm		1.0		12.0	39.8	32.1	15.1(U)	
		367.5-438.5 mm					24.8	67.1	8.1(U)	
		441.0-512.0 mm						100		
		Total Average		4.0		13.5	55.9	16.5	13.7(U)	
Flathead Catfish	L. Carl Blackwell, OK	Adults (>420 mm)	Annual	0.1				99.2	0.7(U)	Turner and Summerfelt (1971)
	L. Eufaula, OK	Adults (>420 mm)	Annual	t			0.3	99.4	0.2(U)	Turner and Sumerfelt (1971)
	L. Ft. Gibson, OK	Adults (>420 mm)	Annual	0.2			0.6	98.4	0.6(U)	Turner and Summerfelt (1971)
	Grand L., OK	Adults (>420 mm)	Annual				t	99.8	0.2(U)	Turner and Summerfelt (1971)
	Hudson L., OK	Adults (>420 mm)	Annual					99.6	0.4(U)	Turner and Summerfelt (1971)
	L. Texoma, OK	Adults (>420 mm)	Annual	t				98.7	1.3(U)	Turner and Summerfelt (1971)
	Big Blue River, KS	<100 mm	Summer				92	3	5(U)	Minckley and Deacon (1959)
		100-245 mm	Summer				47	45	8(U)	
		>245 mm	Summer				9	79	12(U)	
	Neosho R., KS	<100 mm	Summer				96	2	2(U)	Minckley and Decon (1959)
		100-245 mm	Summer				73	26	1(U)	
		>245 mm	Summer				63	37		
Tadpole Madtom	L. Mendota, WI L. Monona, WI L. Wingra, WI L. Waubesa, WI	14-76 mm (34 mm avg.)	May-Jun, Aug	6.0	2.9	14.0	77.4		3.0(U)	Pearse (1916)
Burbot	?	?	?				20	80		Forbes and Richardson (1920)
Banded Killifish	L. Opinicon, Ontario Canada	65-86 mm	May-Sep	5.2		26.0	68.8			Keast (1965)
	Green L., WI	18-55 mm (44 mm avg.)	Aug			16.6	77.5		5.9(I)	Pearse (1921)
	L. Mendota, WI	61 mm avg.	Aug-Sep	4		30	57		9(I)	Pearse (1921)
	L. Mendota, WI L. Monona, WI L. Wingra, WI L. Waubesa, WI	25.4-67.5 mm (40 mm avg.)	Apr-Aug., Dec	6.4	2.7	20.2	62.9		4.2(U)	Pearse (1916)

(Continued)

Appendix E (Continued)

Fish Species	Location of Study	Age of Length	Season	Plant Material	Terrestrial Invertebrates	Zooplankton	Benthic Invertebrates	Fish	Detritus	Reference
Brook Silverside	Beaver L., AR	10-100 mm	Jan-Dec			29.8	39.6		0.4(0)	Mullan et al. (1968)
	Bull Shoals L., AR	10-100 mm	Jan-Dec			19.9	50.4	t		Mullan et al. (1968)
	L. Mendota, WI	59 mm avg	Aug-Sep			40.1	59.9			Pearse (1921)
	L. Lemon, IN	All ages	Jul-Nov	4.8			59.9		35.3(U)	Zimmerman (1970)
	Monroe L., IN	All ages	Jul-Nov	7.5			54.7		37.8(U)	Zimmerman (1970)
	L. Opinicon, Ontario, Canada	40-60 mm	Aug-Sep		8.5	77	14.5			Keast (1965)
		61-81 mm	May, Aug-Sep		29.7	16.3	54.0			
	L. Mendota, WI L. Monona, WI L. Wingra, WI L. Waubesa, WI	11.5-77 mm (41 mm avg.)	Aug	4.0	28.6	40.7	24.3		1.6(U)	Pearse (1916)
White Bass	L. Mendota, WI	235 mm avg.	Aug-Sep	12.2			75.6	12.2		Pearse (1921)
	L. Texoma, OK	16-105 mm	Jun-Oct			t	6	94		Bonn (1952)
		23-165 mm	Jun-Oct			t	4	96		
	L. Mendota, WI L. Monona, WI L. Wingra, WI L. Waubesa, WI	29-220 mm (66 mm avg.)	Jul, Aug-Sep		1.3	45.9	49.1	4.2		Pearse (1916)
	L. Texoma, OK	0-50 mm	Annual		t	2.2	3.5	94.3		Moser (1968)
		51-100 mm			0.2	0.1	1.2	98.6		
		101-150 mm					1.4	98.6		
		151-200 mm			0.1	3.3	3.4	93.2		
		201-250 mm			0.1	0.6	2.3	97.0		
		251-300 mm			0.3	t	4.2	95.4		
		301-350 mm			0.3	t	5.5	94.1		
		351-400 mm			0.2		1.2	98.7		
		401-450 mm					t	100.0		
	L. Erie	24.5-46.5 mm	Summer			91.0	3.0	4.4	1.6(U)	Price (1963)
		49.0-71.0 mm				80.0	2.7	14.7	2.6(U)	
		73.5-95.5 mm				29.5	16.2	53.6	0.7(U)	
		98.0-120.0 mm				14.8	6.1	78.5	0.6(U)	
		147.0-193.5 mm				34.2	4.9	59.0	1.9(U)	
		196.0-242.5 mm				4.9	1.4	91.8	1.9(U)	
		245.0-291.5 mm				t	4.5	94.9	0.6(U)	
		294.0-365.0 mm					23.7	66.4	9.9(U)	
		Total Average				21.3	6.8	70.8	1.1(U)	

(Continued)

Appendix E (Continued)

Fish Species	Location of Study	Age of Length	Season	Plant Material	Terrestrial Invertebrates	Zooplankton	Benthic Invertebrates	Fish	Detritus	Reference
Yellow Bass	Clear L., IA	170-230 mm	Jan-Dec			26.9	49.7	23.4		Bulkley (1970)
		15-70 mm	Jun-Dec			99.4	0.6			
Striped Bass	Albermarle Sound, NC	125-714 mm	Annual	0.1			2.9	97.0		Manooch (1973)
	Culture ponds, OK	10-19 mm	Summer			81.5	18.6			Harper et al. (1969)
		20-29 mm	Summer	1.7		61.2	37.2			
		30-39 mm	Summer			58.0	42.0			
		40-49 mm	Summer			54.4	45.8			
		50-59 mm	Summer			67.5	32.5			
		60-69 mm	Summer			49.6	48.5	2.0		
		70-79 mm	Summer	0.4		37.9	59.2	2.6		
		80-89 mm	Summer	0.6		20.5	70.1	9.0		
		90-99 mm	Summer			0.2	80.0	19.8		
		100-109 mm	Summer				15.0	85.0		
Rock Bass	Green L., WI	30-213 mm (134 mm avg.)	Aug-Sep			12.0	83.6		4.2(I)	Pearse (1921)
	Houghton L., MI	?	?				100.0			Hunt and Carbine (1950)
	L. Mendota, WI	128 mm avg.	Aug-Sep	13.0		14.0	61.8		11.2(I)	Pearse (1921)
	L. Opinicon, Ontario, Canada	45-70 mm	May-Sep	1.2	7.8	17.6	73.4			Keast (1965)
		75-115 mm	May-Sep	0.6	3.4	6.2	83.8	6.0		
	L. Mendota, WI L. Monona, WI L. Wingra, WI L. Waubesa, WI	22.5-230 mm (73 mm avg.)	May-Dec	3.3	7.3	4.6	81.2	2.0	1.2(U)	Pearse (1916)
Green Sunfish	Bull Shoals L., AR	0-49 mm	?	2	12	14	72			Applegate et al. (1967)
		49-98 mm		1	8	12	68	10	1(U)	
		98-196 mm		t	13	t	71	16	1(U)	
	Beaver L., AR	50-100 mm	Jan-Dec	2.3	26.3	t	67.5		3.9(U)	Mullan and Applegate (1970)
		>100 mm	Jan-Dec	7.0	34.0		45.3	8.6	5.1(U)	
	?	?	?				65	35		Forbes and Richardson (1920)

(Continued)

Fish Species	Location of Study	Age of Length	Season	Plant Material	Terrestrial Invertebrates	Zooplankton	Benthic Invertebrates	Fish	Detritus	Reference
Pumpkinseed	Maple L., MN	130 mm	Summer	3		1	94[8]		3(U)	Seaburg and Moyle (1964)
	Grove L., MN	147 mm	Summer	4		1	79[8]		16(U)	Seaburg and Moyle (1964)
	Beaver L., MN	98-135 mm	Jun-Jul	1		t	99[8]			Scidmore and Woods (1960)
		123-245 mm	Jun-Jul			2	98[8]			
		49-98 mm	Jun-Jul				100[8]			
		123-245 mm	Jun-Jul			20	80[8]			
	Houghton L., MI	?	?			t	96.8			Hunt and Carbine (1950)
	Green L., WI	73-168 mm (146 mm avg.)	Sep				100			Pearse (1921)
	L. Mendota, WI	118 mm avg.	Aug-Sep	5.5		14.0	69.4		11.1(I)	Pearse (1921)
	L. Mendota, WI L. Monona, WI L. Wingra, WI L. Waubesa, WI	116-187 mm (146 mm avg.)	Apr, Aug, Oct	25.5	2.1		68.8		2.8(U)	Pearse (1916)
	L. Opinicon, Ontario Canada	60-85 mm	May-Sep	4.6	8.8	19.4	67.2			Keast (1965)
		86-115 mm	May-Sep	6.0	7.2	14.8	67.0	5.0		
		130-170 mm	May-Sep	10.8	18.4	0.4	66.8	3.6		
Bluegill	Bull Shoals L., AR	0-49	Apr-Mar			30	70			Applegate et al. (1967)
		49-98 mm	Apr-Mar	13	26	4	55		t(U)	
		98-196 mm	Apr-Mar	23	23	t	46	6	1(U)	
	Maple L., MN	123-196 mm	Summer	21		5	61[8]		12(U)	Seaburg and Moyle (1964)
	Grove L., MN	123-196 mm	Summer	16		19	46[8]	6	13(U)	Seaburg and Moyle (1964)
	Beaver L., AR	<50 mm	May-Jun			7.4	92.6			Mullan and Applegate (1970)
		50-100 mm	Feb-Oct	1.1	15.0	13.7	68.5		1.7(U)	
		>100 mm	Jan-Dec	4.3	39.9	1.8	49.9	0.9	3.2(U)	
	Clear L., MN	56-86 mm	Jun-Jul			5	84[8]		11(U)	Scidmore and Woods (1960)
		110-159 mm	Jun-Jul			t	99[8]		t(U)	
	Beaver L., MN	135-159 mm	Jun-Jul	20		t	73[8]		7(U)	Scidmore and Woods (1960)
		123-270 mm	Jun-Jul	1		23	76[8]			
		61-98 mm	Jun-Jul				100[8]			
	St. Olaf L., MN	86-115 mm	Jun-Jul	41		19	27[8]		13(U)	Scidmore and Woods (1960)
		<74 mm	Jun-Jul	36		9	47[8]		8(U)	
		123-245 mm	Jun-Jul			100				
		<123 mm	Jun-Jul			30	70[8]			

(Continued)

Appendix E (Continued)

Fish Species	Location of Study	Age of Length	Season	Plant Material	Terrestrial Invertebrates	Zooplankton	Benthic Invertebrates	Fish	Detritus	Reference
Bluegill (Con't)	Green L., WI	43-188 mm (165 mm avg.)	Aug-Sep	23.0		t	72.6		2.2(O); 2.2(I)	Pearse (1921)
	L. Mendota, WI	127 mm avg.	Aug-Sep	85.6			14.4			Pearse (1921)
	Houghton L., MI	?	?				100			Hunt and Carbine (1950)
	L. Mendota, WI L. Monona, WI L. Wingra, WI L. Waubesa, WI	15-115 mm (51 mm avg.)	Apr-Aug	5.2	1.3	24.5	66.6		2.2(U)	Pearse (1916)
Longear Sunfish	Bull Shoals L., AR	0-49 mm	Apr-Mar			44	56			Applegate et al. (1967)
		49-98 mm	Apr-Mar	2	9	1	83		5(U)	
		98-196 mm	Apr-Mar	5	37	3	24	29	3(U)	
	Beaver L., AR	50-100 mm	Feb-Dec		5.9		93.2		0.8(U)	Mullan and Applegate (1970)
		>100 mm	Jan-Dec	5.0	35.3	t	53.0	1.5	5.2(U)	
Smallmouth Bass	Bull Shoals L., AR	49-98 mm	Apr-Mar		2	21	33	38	6(U)	Applegate et al. (1967)
		98-196 mm	Apr-Mar	t	t	t	5	93	1(U)	
		>196 mm	Apr-Mar		1		5	94	t(U)	
	Green L., WI	46-395 mm (114 mm avg.)	Aug	0.2		37.6	46.6	13.6	2.0(U)	Pearse (1921)
	L. Mendota, WI	356 mm avg.	Aug-Sep	5.0			85.5		9.5(O)	Pearse (1921)
	L. Mendota, WI L. Monona, WI L. Wingra, WI L. Waubesa, WI	29-181 mm (72 mm avg.)	Aug	1.4	13.9	3.4	63.5	14.7	1.5(U)	Pearse (1916)
	?	?	?				67	33		Forbes and Richardson (1920)
Spotted Bass	Beaver L., AR	<50 mm	Jun		64.2	10.0	25.7			Mullan and Applegate (1970)
		50-100 mm	Jun-Dec		2.4	6.2	51.2	40.2		
		101-200 mm	Mar-Oct		26.0		25.6	48.1	0.2(U)	
		>200 mm	Mar-Dec		11.5		46.8	40.3	1.4(U)	
	Bull Shoals L., AR	0-49 mm	Apr-Mar			21	79			Applegate et al. (1967)
		49-98 mm	Apr-Mar		2	14	28	56		
		98-196 mm	Apr-Mar	1	2	t	11	85	1(U)	
		>196 mm	Apr-Mar				7	91	2(U)	

(Continued)

Appendix E (Continued)

Fish Species	Location of Study	Age of Length	Season	Plant Material	Terrestrial Invertebrates	Zooplankton	Benthic Invertebrates	Fish	Detritus	Reference
Largemouth Bass	Bull Shoals L., AR	0-49 mm	Apr-Mar			99	1			Applegate et al. (1967)
		49-98 mm	Apr-Mar				50	50		
		98-196 mm	Apr-Mar		t		1	99	t(U)	
		>196 mm	Apr-Mar		t		12	88	t(U)	
	Beaver L., AR	<50 mm	May-Aug		5.9	20.6	53.7	19.8		Mullan and Applegate (1970)
		50-100 mm	Apr-Dec		12.3	11.8	40.3	32.1	3.5(U)	
		101-200 mm	Jan-Dec		26.6		5.0	66.5	1.9(U)	
		>200 mm	Jan-Dec		9.2		16.9	68.3[9]	4.6(U)	
	Maple L., MN	186 mm	Summer	1				96[10]		Seaburg and Moyle (1964)
	St. Olaf L., MN	83-132 mm	Jun-Jul			30	40[8]	30		Scidmore and Woods (1960)
	Beaver L., AR	Young-of-the-Year (24-66 mm)	May			48.0	34.8[8]	17.2		Applegate and Mullan (1967)
		Young-of-the-Year (24-66 mm)	Jun			1.8	19.3[8]	78.9		
	Bull Shoals L., AR	Young-of-the-Year (18-41 mm)	May			99.9	0.1[8]			Applegate and Mullan (1967)
		Young-of-the-Year (18-41 mm)	Jun			38.5	1.2[8]	60.3		
	Green L., WI	49-283 mm (78 mm avg.)	Aug	5.2		24.8	67.6[8]	1.0	1.4(I)	Pearse (1921)
	L. Mendota, WI	135 mm avg.	Aug-Sep	17.8		0.8	36.4[8]	45.0		Pearse (1921)
	L. Opinicon, Ontario, Canada	30-50 mm	Jun-Sep			46.0	48.5	5.5		Keast (1965)
		51-70 mm	Jun-Sep		0.8	6.5	87.9	4.8		
		80-120 mm	May-Sep	2.0			23.4	74.6		
	L. Mendota, WI L. Monona, WI L. Wingra, WI L. Waubesa, WI	29.5-470 mm (67 mm avg.)	Apr-Nov	1.9	9.6	18.0	61.9	8.7	0.1(U)	Pearse (1916)
	?	?	?				7	93		Forbes and Richardsong (1920)
	Murphy Flowage, WI	Adult	Summer	1.1	1.1		59.0[8]	38.8		Snow (1971)
White Crappie	Conowingo L., PA	Adult	Jun-Dec			28.0	27.6	42.0	2.4(U)	Mathur (1972)
	Conowingo L., PA	Young	Jul-Jun	t		100	t			Mathur and Robbins (1971)

(Continued)

Fish Species	Location of Study	Age of Length	Season	Plant Material	Terrestrial Invertebrates	Zooplankton	Benthic Invertebrates	Fish	Detritus	Reference
White Crappie (Con't)	Volney L., MN	74-98 mm	Jun-Jul			100				Scidmore and Woods (1960)
	Beaver L., MN	147-172 mm	Jun-Jul			79	7	3	10(U)	Scidmore and Woods (1960)
		123-270 mm	Jun-Jul			66	29	5		
		123-270 mm	Jun-Jul			70	30			
	?	?	?			9	80	11		Forbes and Richardson (1920)
Black Crappie	Maple L., MN	162 mm	Summer			1	36	60	3(U)	Seaburg and Moyle (1964)
	Grove L., MN	165 mm	Summer			12	49	23	16(U)	Seaburg and Moyle (1964)
	Clear L., MN	86-105 mm	Jun-Jul			99	1			Scidmore and Woods (1960)
		140-164 mm	Jun-Jul			76	15		9(U)	
		49 mm	Jun-Jul	4		58	20	18		
		123-267 mm	Jun-Jul	9		90	1			
		123-245 mm	Jun-Jul			95	t	5		
	Beaver L., MN	147 mm	Jun-Jul			85	t		15(U)	Scidmore and Woods (1960)
		123-270 mm	Jun-Jul			72	28			
		123-270 mm	Jun-Jul			95	5			
	L. Mendota, WI L. Monona, WI L. Wingra, WI L. Waubesa, WI	35-221 mm (90 mm avg.)	Apr-May Jul-Nov	1.3	6.2	35.2	51.6	7.1	0.1(U)	Pearse (1916)
	L. Mendota, WI	131 mm avg.	Aug-Sep	13.3		20.2	49.9	16.6		Pearse (1921)
	Orange L., FL	Adult	Jun-May			5	5	90		Reid (1949)
	Pend Oreille L., ID	?	?			t	t	100		Jeppson and Platts (1959)
	Hayden L., ID	?	?	4		4	82	10		Jeppson and Platts (1959)
	L. Opinicon, Ontario, Canada	75-115 mm	May-Sep	1.2	8.2	27.6	57.4	5.6		Keast (1965)
	L. Opinicon, Ontario, Canada	60-115 mm	May-Sep		4.4	18.8	70.2	6.6		Keast (1968)
		116-160 mm	May-Sep		3.2	10.6	68.4	17.8		
		161-240 mm	May-Sep		0.6	1.0	63.6	34.8		
Logperch	Beaver L., AR	?	Apr-Nov				98.6		1.4(U)	Mullan et al. (1968)
	Bull Shoals L., AR	?	Apr-Nov			23.7	74.0		2.3(O)	Mullan et al. (1968)
	L. Vermilion, MN	61 mm	Summer			1.2	98.8	t		Dobie (1959)

(Continued)

Appendix E (Continued)

Fish Species	Location of Study	Age of Length	Season	Plant Material	Terres-trial Inverte-brates	Zoo-plankton	Benthic Inverte-brates	Fish	Detritus	Reference
Logperch (Con't)	L. Opinicon, Ontario, Canada	Adults	May-Oct				100			Keast and Webb (1966)
	L. Mendota, WI L. Monona, WI L. Wingra, WI L. Waubesa, WI	44-100 mm (73 mm avg.)	Apr, Jun-Sep		0.6	0.4	93.4		5.7(U)	Pearse (1916)
	?	?	?			33	67			Forbes and Richardson (1920)
Iowa Darter	Houghton L., MI	?	?	t		3.8	96.2			Hunt and Carbine (1950)
	L. Mendota, WI L. Monona, WI L. Wingra, WI L. Waubesa, WI	48 mm avg.	Jul-Aug				99.6		0.4(U)	Pearse (1916)
Blackside Darter	Houghton L., MI	?	?			t	100			Hunt and Carbine (1950)
Johnny Darter	Green L., WI	32-47 mm (38 mm avg.)	Aug				84.7		15.3(I)	Pearse (1921)
	L. Mendota, WI	46 mm avg.	Aug-Sep	13.6			62.8		2.9(O); 20.7(I)	Pearse (1921)
	L. Mendota, WI L. Monona, WI L. Wingra, WI L. Waubesa, WI	21.5-48.5 mm (31 mm avg.)	Jul-Sep	t	0.1	13.0	84.6		3.1(I)	Pearse (1916)
	?	?	?				100			Forbes and Richardson (1920)
Fantailed Darter	L. Mendota, WI L. Monona, WI L. Wingra, WI L. Waubesa, WI	29.6-48.3 mm (37 mm avg.)	Jul-Sep, Dec	1.0	0.2	0.2	98.5			Pearse (1916)
	?	?	?			8	92			Forbes and Richardson (1920)
Eastern Sand Darter	?	?	?				100			Forbes and Richardson (1920)

(Continued)

Appendix E (Continued)

Fish Species	Location of Study	Age of Length	Season	Plant Material	Terrestrial Invertebrates	Zooplankton	Benthic Invertebrates	Fish	Detritus	Reference
Blueside Darter	?	?	?				100			Forbes and Richardson (1920)
Swamp Darter	?	?	?				100			Forbes and Richardson (1920)
Yellow Perch	Maple L., MN	130 mm	Summer			1	37	59	3(U)	Seaburg and Moyle (1964)
	Grove L., MN	147 mm	Summer			3	41	39	17(U)	Seaburg and Moyle (1964)
	Beaver L., MN	135-147 mm 123-270 mm 98-123 mm	Jun-Jul Jun-Jul Jun-Jul				100 100 100			Scidmore and Woods (1960)
	St. Olaf L., MN	<123 mm	Jun-Jul			9	85	6		Scidmore and Woods (1960)
	L. Opinicon, Ontario, Canada	60-110 mm	May-Sep			12.8	72.6	14.6		Keast (1965)
	Cocolalla L., ID	?	?				100			Jeppson and Platts (1959)
	Pend Oreille L., ID	?	?	1		t	95	4		Jeppson and Platts (1959)
	Hayden L., ID	?	?	t			93	7		Jeppson and Platts (1959)
	Houghton L., MI	?	?			1.7	35.4	62.7		Hunt and Carbine (1950)
	L. Mendota, WI L. Monona, WI L. Wingra, WI L. Waubesa, WI	25-280 mm (100 mm avg.)	May-Oct, Dec	1.5		25.4	68.5	3.0[11]	1.1(U)	Pearse (1916)
	?	?	?				94	6		Forbes and Richardson (1920)
	Green L., WI	73-268 mm (112 mm avg.)	Aug-Sep	3.8		10.7	83.1	0.5	0.9(O); 1.0(I)	Pearse (1921)
	L. Mendota, WI	166 mm avg.	Aug-Sep	7.0		42.3	49.8		0.9(O)	Pearse (1921)
	L. Erie	24.5-46.5 mm	Summer			100				Price (1963)
		49.0-71.0 mm				65.6	32.9		1.5(U)	
		73.5-95.5 mm				48.4	50.8		0.8(U)	
		98.0-144.5 mm				28.6	65.2	2.5	3.7(U)	
		147.0-193.5 mm				19.4	67.3	10.7	2.6(U)	
		196.0-242.5 mm				10.1	50.7	34.5	4.7(U)	
		Total Average				19.4	65.0	12.6	3.0(U)	
Sauger	?	?	?					100		Forbes and Richardson (1920)

(Continued)

Appendix E (Continued)

Fish Species	Location of Study	Age of Length	Season	Plant Material	Terrestrial Invertebrates	Zooplankton	Benthic Invertebrates	Fish	Detritus	Reference
Walleye	Clear L., MN	118-125 mm	Jun-Jul	6		51	43			Scidmore and Woods (1960)
		123-267 mm	Jun-Jul	5		90			5(U)	
		245 mm	Jun-Jul					100		
	L. Mendota, WI	410 mm avg.	Aug-Sep					100		Pearse (1921)
	L. Mendota, WI L. Monona, WI L. Wingra, WI L. Waubesa, WI	425, 448 mm	Sep, Nov					90.9[12]		Pearse (1916)
	?	?	?					100		Forbes and Richardson (1920)
	L. Erie	24.5-193.5 mm	Summer					100.0		Price (1963)
		196.0-242.5 mm						97.5	2.5(U)	
		245.0-291.5 mm						100.0		
		294.0-365.0 mm				t	0.1	99.4	0.4(U)	
		367.5-438.5 mm		t			1.5	96.5	2.0(U)	
		441.0-512.0 mm					0.2	99.0	0.8(U)	
		514.5-585.5 mm						100.0		
		Total Average		t		t	0.4	98.9	0.7(U)	
Freshwater Drum	Grand L., OK	Adults (254-322 mm)	Sep-Aug				1.0	94.6	4.4(O)	Summerfelt et al. (1972)
	L. Ft. Gibson, OK	Adults (254-322 mm)	Sep-Aug				32.0	63.9	4.0(O)	Summerfelt et al. (1972)
	L. Eufaula, OK	Adults (254-322 mm)	Sep-Aug				61.9	0.7	37.4(O)	Summerfelt et al. (1972)
	L. Texoma, OK	Adults (254-322 mm)	Sep-Aug				11.4	80.0	8.6(O)	Summerfelt et al. (1972)
	Lewis and Clark L., SD	Age O (6-120 mm)	Jul-Sep			18.3	81.7			Swedberg (1968)
		Age O (6-120 mm)	Jun-Nov			57.8	42.2			
		Age I	Apr-Nov			24.4	75.0	0.6		
		Adult	Apr-Nov			12.8	84.4	2.8		
	Clear L., MN	93-140 mm	Jun-Jul			t	99			Scidmore and Woods (1960)
		<74 mm	Jun-Jul	11		t	89			
		<245 mm	Jun-Jul				40		60(U)	

(Continued)

Appendix E (Concluded)

Fish Species	Location of Study	Age of Length	Season	Plant Material	Terrestrial Invertebrates	Zooplankton	Benthic Invertebrates	Fish	Detritus	Reference
Freshwater Drum (Con't)	Volney L., MN	264-392 mm	Jun-Jul				100			Scidmore and Woods (1960)
		123-267 mm	Jun-Jul				100			
		264-392 mm	Jun-Jul	2			98			
		123-243 mm	Jun-Jul				100			
		245-368 mm	Jun-Jul				100			
	L. Erie	24.5-46.5 mm	Summer			22.7	72.7		4.6(U)	Price (1963)
		49.0-71.0 mm				26.6	66.2		7.2(U)	
		73.5-95.5 mm				11.9	81.0		7.1(U)	
		98.0-144.5 mm				21.2	75.2		3.6(U)	
		147.0-193.5 mm				13.5	79.4	5.1	2.0(U)	
		196.0-242.5 mm				5.1	91.3	0.6	3.0(U)	
		245.0-291.5 mm		t		1.9	86.8	4.6	6.7(U)	
		294.0-365.0 mm		0.1		0.8	64.4	29.1	6.4(U)	
		367.5-438.5 mm				0.1	37.7	58.0	4.2(U)	
		441.0-512.0 mm					13.5	83.6	2.9(U)	
		Total Average		t		3.1	68.2	23.5	5.2(U)	
Common Sculpin	?	?	?				75.0	25.0		Forbes and Richardson (1920)
	L. Mendota, WI L. Monona, WI L. Wingra, WI L. Waubesa, WI	20.5-57.5 mm (40 mm avg.)	Jul-Oct	1.1	1.0	1.3	95.0		0.2(I)	Pearse (1916)
Brook Stickleback	L. Houghton, MI	?	?			32.4	67.6			Hunt and Carbine (1950)
	L. Mendota, WI L. Monona, WI L. Wingra, WI L. Waubesa, WI	9.4-51.0 mm (29 mm avg.)	Apr, Jun-Jul	4.4	7.3	35.3	48.3		3.7(U)	Pearse (1916)

APPENDIX F: DISTRIBUTION OF FISH BIOMASS AMONG FISH FOOD COMPARTMENTS ARRANGED BY MAJOR RESERVOIR GROUPS (SIMILAR SPECIES COMPOSITION AND STANDING CROPS) AND DISTRIBUTION OF CARRYING CAPACITY BIOMASS, ANNUAL FISH PRODUCTION, AND YOUNG-OF-THE-YEAR (Y-O-Y) PRODUCTION AMONG THE FOOD COMPARTMENTS

Appendix F (Continued)

Reservoir Group: White River Basin

Expected annual production: 148.0 lb/acre

A. Y-O-Y Shad component 42.9 lb/acre		B. Y-O-Y component exluding Shad 23.7 lb/acre	C. Age 1 + component 81.4 lb/acre
1. Detritus	10.7	1. Detritus 7.1	1. Detritus 35.9
2. Benthos	2.2	2. Benthos 7.1	2. Benthos 25.2
3. Zooplankton	30.0	3. Zooplankton 5.9	3. Zooplankton 7.3
		4. Fish 2.4	4. Fish 11.4
		5. Terrestrial 1.2	5. Terrestrial 1.6

	Detritus	Benthos	Zooplankton	Fish	Terrestrial
a. Expected annual production, lb/acre	53.70	34.50	43.20	13.80	2.80
b. Expected annual production, g/m^2 (dry weight) (a × 0.0280)	1.50	0.97	1.21	0.39	0.08
c. Food needed to produce one gram of the annual production, g (dry weight)	1.00	1.00	0.50	1.25	1.00
d. Food needed to produce the expected annual production, g/m^2 (dry weight) (b × c)	1.50	0.97	0.61	0.49	0.08
e. Carrying capacity standing crop, lb/acre	93.20	65.30	17.90	30.60	4.30
f. Carrying capacity standing crop, g/m^2 (dry weight) (e × 0.0280)	2.61	1.83	0.50	0.86	0.12
g. Food needed to support one gram of carrying capacity standing crop, g (dry weight)	0.25	0.25	0.125	0.3125	0.25
h. Food needed to support the total carrying capacity standing crop, g/m^2 (dry weight) (f × g)	0.65	0.46	0.06	0.27	0.03
i. Annual food transfer to fish, g/m^2 (dry weight) (d + h)	2.15	1.43	0.67	0.76	0.11

(Continued)

Reservoir Group: Red River Basin

Expected annual production: 137.7 lb/acre

A. Y-O-Y Shad component 39.9 lb/acre
   1. Detritus 10.0
   2. Benthos 2.0
   3. Zooplankton 27.9

B. Y-O-Y component exluding Shad 22.0 lb/acre
   1. Detritus 6.6
   2. Benthos 6.6
   3. Zooplankton 5.5
   4. Fish 2.2
   5. Terrestrial 1.1

C. Age 1 + component 75.7 lb/acre
   1. Detritus 31.0
   2. Benthos 25.1
   3. Zooplankton 1.6
   4. Fish 15.1
   5. Terrestrial 2.9

	Detritus	Benthos	Zooplankton	Fish	Terrestrial
a. Expected annual production, lb/acre	47.60	33.70	35.00	17.30	4.00
b. Expected annual production, g/m^2 (dry weight) (a × 0.0280)	1.33	0.94	0.98	0.48	0.11
c. Food needed to produce one gram of the annual production, g (dry weight)	1.00	1.00	0.50	1.25	1.00
d. Food needed to produce the expected annual production, g/m^2 (dry weight) (b × c)	1.33	0.94	0.49	0.60	0.11
e. Carrying capacity standing crop, lb/acre	80.40	65.30	4.10	39.30	7.50
f. Carrying capacity standing crop, g/m^2 (dry weight) (e × 0.0280)	2.25	1.83	0.11	1.10	0.21
g. Food needed to support one gram of carrying capacity standing crop, g (dry weight)	0.25	0.25	0.125	0.3125	0.25
h. Food needed to support the total carrying capacity standing crop, g/m^2 (dry weight) (f × g)	0.56	0.46	0.01	0.34	0.05
i. Annual food transfer to fish, g/m^2 (dry weight) (d + h)	1.89	1.40	0.50	0.94	0.16

(Continued)

Reservoir Group: Green and Cumberland Rivers and Dewey

Expected annual production: 135.8 lb/acre

A. Y-O-Y Shad component	39.4 lb/acre	B. Y-O-Y component exluding Shad	21.7 lb/acre	C. Age 1 + component	74.7 lb/acre
1. Detritus	9.8	1. Detritus	6.5	1. Detritus	36.4
2. Benthos	2.0	2. Benthos	6.5	2. Benthos	20.7
3. Zooplankton	27.6	3. Zooplankton	5.4	3. Zooplankton	5.5
		4. Fish	2.2	4. Fish	10.6
		5. Terrestrial	1.1	5. Terrestrial	1.4

	Detritus	Benthos	Zooplankton	Fish	Terrestrial
a. Expected annual production, lb/acre	52.70	29.20	38.50	12.80	2.50
b. Expected annual production, g/m^2 (dry weight) (a × 0.0280)	1.48	0.82	1.08	0.36	0.07
c. Food needed to produce one gram of the annual production, g (dry weight)	1.00	1.00	0.50	1.25	1.00
d. Food needed to produce the expected annual production, g/m^2 (dry weight) (b × c)	1.48	0.82	0.54	0.45	0.07
e. Carrying capacity standing crop, lb/acre	94.40	53.70	14.30	27.50	3.50
f. Carrying capacity standing crop, g/m^2 (dry weight) (e × 0.0280)	2.64	1.50	0.40	0.77	0.10
g. Food needed to support one gram of carrying capacity standing crop, g (dry weight)	0.25	0.25	0.125	0.3125	0.25
h. Food needed to support the total carrying capacity standing crop, g/m^2 (dry weight) (f × g)	0.66	0.38	0.05	0.24	0.03
i. Annual food transfer to fish, g/m^2 (dry weight) (d + h)	2.14	1.20	0.59	0.69	0.10

(Continued)

Appendix F (Continued)

Reservoir Group: Blue Mountain, Nimrod, and Wister

Expected annual production: 354.4 lb/acre

A. Y-O-Y Shad component	70.9 lb/acre	B. Y-O-Y component exluding Shad	88.6 lb/acre	C. Age 1 + component	194.9 lb/acre
1. Detritus	17.7	1. Detritus	26.6	1. Detritus	77.6
2. Benthos	3.6	2. Benthos	26.6	2. Benthos	29.2
3. Zooplankton	49.6	3. Zooplankton	22.2	3. Zooplankton	55.0
		4. Fish	8.9	4. Fish	31.8
		5. Terrestrial	4.4	5. Terrestrial	1.2

	Detritus	Benthos	Zooplankton	Fish	Terrestrial
a. Expected annual production, lb/acre	121.90	59.4	126.80	40.70	5.60
b. Expected annual production, g/m^2 (dry weight) (a × 0.0280)	3.41	1.66	3.55	1.14	0.16
c. Food needed to produce one gram of the annual production, g (dry weight)	1.00	1.00	0.50	1.25	1.00
d. Food needed to produce the expected annual production, g/m^2 (dry weight) (b × c)	3.41	1.66	1.78	1.43	0.16
e. Carrying capacity standing crop, lb/acre	201.50	75.90	142.80	82.50	3.00
f. Carrying capacity standing crop, g/m^2 (dry weight) (e × 0.0280)	5.64	2.13	4.00	2.31	0.08
g. Food needed to support one gram of carrying capacity standing crop, g (dry weight)	0.25	0.25	0.125	0.3125	0.25
h. Food needed to support the total carrying capacity standing crop, g/m^2 (dry weight) (f × g)	1.41	0.53	0.50	0.72	0.02
i. Annual food transfer to fish, g/m^2 (dry weight) (d + h)	4.82	2.19	2.28	2.15	0.18

(Continued)

Reservoir Group: Lower Mississippi Valley

Expected annual production: 177.2 lb/acre

A. Y-O-Y Shad component	39.0 lb/acre	B. Y-O-Y component exluding Shad	40.8 lb/acre	C. Age 1 + component	97.5 lb/acre
1. Detritus	9.8	1. Detritus	12.2	1. Detritus	39.8
2. Benthos	2.0	2. Benthos	12.2	2. Benthos	16.5
3. Zooplankton	27.3	3. Zooplankton	10.2	3. Zooplankton	16.8
		4. Fish	4.1	4. Fish	23.2
		5. Terrestrial	2.0	5. Terrestrial	1.1

	Detritus	Benthos	Zooplankton	Fish	Terrestrial
a. Expected annual production, lb/acre	61.80	30.70	54.30	27.30	3.10
b. Expected annual production, g/m^2 (dry weight) (a × 0.0280)	1.73	0.86	1.52	0.76	0.09
c. Food needed to produce one gram of the annual production, g (dry weight)	1.00	1.00	0.50	1.25	1.00
d. Food needed to produce the expected annual production, g/m^2 (dry weight) (b × c)	1.73	0.86	0.76	0.95	0.09
e. Carrying capacity standing crop, lb/acre	103.30	42.80	43.50	60.20	2.80
f. Carrying capacity standing crop, g/m^2 (dry weight) (e × 0.0280)	2.89	1.20	1.22	1.69	0.08
g. Food needed to support one gram of carrying capacity standing crop, g (dry weight)	0.25	0.25	0.125	0.3125	0.25
h. Food needed to support the total carrying capacity standing crop, g/m^2 (dry weight) (f × g)	0.72	0.30	0.15	0.53	0.02
i. Annual food transfer to fish, g/m^2 (dry weight) (d + h)	2.45	1.16	0.91	1.48	0.11

(Continued)

Reservoir Group: Gulf and South Atlantic

Expected annual production: 79.0 lb/acre

A. Y-O-Y Shad component	17.4 lb/acre	B. Y-O-Y component exluding Shad	18.2 lb/acre	C. Age 1 + component	43.4 lb/acre
1. Detritus	4.4	1. Detritus	5.5	1. Detritus	17.5
2. Benthos	0.9	2. Benthos	5.5	2. Benthos	12.9
3. Zooplankton	12.2	3. Zooplankton	4.6	3. Zooplankton	1.9
		4. Fish	1.8	4. Fish	9.5
		5. Terrestrial	0.9	5. Terrestrial	1.5

	Detritus	Benthos	Zooplankton	Fish	Terrestrial
a. Expected annual production, lb/acre	27.40	19.30	18.70	11.30	2.40
b. Expected annual production, g/m^2 (dry weight) (a × 0.0280)	0.76	0.54	0.52	0.32	0.07
c. Food needed to produce one gram of the annual production, g (dry weight)	1.00	1.00	0.50	1.25	1.00
d. Food needed to produce the expected annual production, g/m^2 (dry weight) (b × c)	0.76	0.54	0.26	0.40	0.07
e. Carrying capacity standing crop, lb/acre	45.60	33.50	5.00	24.60	3.90
f. Carrying capacity standing crop, g/m^2 (dry weight) (e × 0.0280)	1.28	0.94	0.14	0.69	0.11
g. Food needed to support one gram of carrying capacity standing crop, g (dry weight)	0.25	0.25	0.125	0.3125	0.25
h. Food needed to support the total carrying capacity standing crop, g/m^2 (dry weight) (f × g)	0.32	0.24	0.02	0.22	0.03
i. Annual food transfer to fish, g/m^2 (dry weight) (d + h)	1.08	0.78	0.28	0.62	0.10

(Continued)

Reservoir Group: Buckhorn, Sutton, Summersville, and Flannagan

Expected annual production: 42.7 lb/acre

A.	Y-O-Y Shad component	0.4 lb/acre	B.	Y-O-Y component exluding Shad	12.8 lb/acre	C. Age 1 + component	29.5 lb/acre
	1. Detritus	0.1		1. Detritus	3.8	1. Detritus	3.0
	2. Benthos	0		2. Benthos	3.8	2. Benthos	20.6
	3. Zooplankton	0.3		3. Zooplankton	3.2	3. Zooplankton	1.5
				4. Fish	1.3	4. Fish	3.0
				5. Terrestrial	0.6	5. Terrestrial	1.5

	Detritus	Benthos	Zooplankton	Fish	Terrestrial
a. Expected annual production, lb/acre	6.90	24.40	5.00	4.30	2.30
b. Expected annual production, g/m^2 (dry weight) (a × 0.0280)	0.19	0.68	0.14	0.12	0.06
c. Food needed to produce one gram of the annual production, g (dry weight)	1.00	1.00	0.50	1.25	1.00
d. Food needed to produce the expected annual production, g/m^2 (dry weight) (b × c)	0.19	0.68	0.07	0.15	0.06
e. Carrying capacity standing crop, lb/acre	6.10	42.70	3.00	6.10	3.00
f. Carrying capacity standing crop, g/m^2 (dry weight) (e × 0.0280)	0.17	1.20	0.08	0.17	0.08
g. Food needed to support one gram of carrying capacity standing crop, g (dry weight)	0.25	0.25	0.125	0.3125	0.25
h. Food needed to support the total carrying capacity standing crop, g/m^2 (dry weight) (f × g)	0.04	0.30	0.01	0.05	0.02
i. Annual food transfer to fish, g/m^2 (dry weight) (d + h)	0.23	0.98	0.08	0.20	0.08

(Continued)

Appendix F (Concluded)

Reservoir Group: Arkansas River Basin*

Expected annual production: 312.8 lb/acre

A. Y-O-Y Shad component	90.8 lb/acre	B. Y-O-Y component exluding Shad	50.0 lb/acre	C. Age 1 + component	172.0 lb/acre
1. Detritus	22.7	1. Detritus	15.0	1. Detritus	88.4
2. Benthos	4.5	2. Benthos	15.0	2. Benthos	33.0
3. Zooplankton	63.6	3. Zooplankton	12.5	3. Zooplankton	22.4
		4. Fish	5.0	4. Fish	26.7
		5. Terrestrial	2.5	5. Terrestrial	1.5

	Detritus	Benthos	Zooplankton	Fish	Terrestrial
a. Expected annual production, lb/acre	126.10	52.50	98.50	31.70	4.00
b. Expected annual production, g/m^2 (dry weight) (a × 0.0280)	3.53	1.47	2.76	0.89	0.11
c. Food needed to produce one gram of the annual production, g (dry weight)	1.00	1.00	0.50	1.25	1.00
d. Food needed to produce the expected annual production, g/m^2 (dry weight) (b × c)	3.53	1.47	1.38	1.11	0.11
e. Carrying capacity standing crop, lb/acre	229.70	85.80	58.10	69.30	3.90
f. Carrying capacity standing crop, g/m^2 (dry weight) (e × 0.0280)	6.43	2.40	1.63	1.94	0.11
g. Food needed to support one gram of carrying capacity standing crop, g (dry weight)	0.25	0.25	0.125	0.3125	0.25
h. Food needed to support the total carrying capacity standing crop, g/m^2 (dry weight) (f × g)	1.61	0.60	0.20	0.61	0.03
i. Annual food transfer to fish, g/m^2 (dry weight) (d + h)	5.14	2.07	1.58	1.72	0.14

*Excluding Blue Mountain, Nimrod, Wister, and Great Salt Plains.

APPENDIX G: FISH CARRYING CAPACITY ARRANGED BY SPECIES AND MAJOR RESERVOIR GROUPS

Appendix C

Fish Carrying Capacity Arranged by Species and Major Reservoir Groups

Species or Species Group	Carrying Capacity	Carrying Capacity Biomass in Pounds per Acre Supported by Each Food Compartment				
		Detritus	Benthos	Zooplankton	Fish	Terrestrial
Gulf and South Atlantic Drainage Area						
Gars	0.6				0.6	
Bowfin	0.5				0.5	
Gizzard shad	25.5	24.2	1.3			
Threadfin shad	6.4	4.5	1.9			
Pickerels	0.8				0.8	
Carp	18.1	10.9	5.4	1.8		
Minnows	0.7		0.1	0.6		
Carpsuckers						
Suckers	5.2	4.2	0.3	0.8		
Hog suckers						
Buffalofishes						
Redhorses	5.2		5.2			
Bullheads	2.5	0.7	1.4		0.5	
Catfishes	6.8		1.2		5.5	
Madtoms						
Silversides						
Temperate basses	0.8				0.8	
Sunfish	18.8	0.9	12.8		1.7	3.4
Black basses	10.0		0.8		8.6	0.6
Crappies	8.2	0.3	1.7	1.5	4.8	0.6
Perches	1.4		0.3	0.3	0.9	
Freshwater drum						
All other species	1.2		1.2			
Total	112.8	45.7	33.6	4.9	24.7	4.0
Buckhorn, Flannagan, Sutton, and Summersville Reservoirs Drainage Area						
Gars						
Bowfin						
Gizzard shad						
Threadfin shad	0.8	0.5	0.2			
Pickerels						
Carp	1.4	0.9	0.4	0.1		
Minnows	1.2		0.2	1.0		
Carpsuckers	0.2	0.2	0.01	0.03		
Suckers	0.2	0.2	0.01	0.03		
Hog suckers	1.1	0.9	0.1	0.2		
Buffalofishes						
Redhorses	17.8		17.8			
Bullheads	0.8	0.2	0.5		0.2	
Catfishes	3.2		0.6		2.7	
Madtoms						
Silversides						
Temperate basses	0.1				0.1	
Sunfish	17.6	0.9	12.0		1.6	3.2

(Continued)

Species or Species Group	Carrying Capacity	Carrying Capacity Biomass in Pounds per Acre Supported by Each Food Compartment: Detritus	Benthos	Zooplankton	Fish	Terrestrial
Buckhorn, Flannagan, Sutton, and Summersville Reservoirs Drainage Area (Continued)						
Black basses	11.5		0.9		9.9	0.7
Crappies	3.1	0.1	0.6	0.6	1.8	
Perches	0.6		0.1	0.1	0.3	
Freshwater drum	1.4	0.1	0.8		0.5	
All other species	0.1		0.1			
Total	61.0	3.9	34.3	2.0	17.0	3.9
Green and Cumberland Rivers and Dewey Reservoir Drainage Area						
Gars	0.1				0.1	
Bowfin						
Gizzard shad	60.6	57.6	3.0			
Threadfin shad	5.6	3.9	1.7			
Pickerels						
Carp	32.4	19.4	9.7	3.2		
Minnows	0.5		0.1	0.4		
Carpsuckers	0.4	0.3	0.02	0.1		
Suckers	4.1	3.3	0.2	0.6		
Hog suckers						
Buffalofishes	16.7	7.5	0.8	8.3		
Redhorses	15.8		15.8			
Bullheads	2.0	0.5	1.1		0.4	
Catfishes	6.2		1.1		5.1	
Madtoms						
Silversides						
Temperate basses	1.3				1.3	
Sunfish	15.8	0.8	10.7		1.4	2.8
Black basses	11.5		0.9		9.9	0.7
Crappies	8.2	0.3	1.7	1.5	4.8	
Perches	1.5		0.3	0.3	0.9	
Freshwater drum	10.8	0.9	6.3		3.7	
All other species	0.3		0.3			
Total	193.9	94.6	53.8	14.4	27.6	3.5
Lower Mississippi Valley Drainage Area						
Gars	4.9				4.9	
Bowfin	0.4				0.4	
Gizzard shad	62.5	59.4	3.1			
Threadfin shad						
Pickerels						
Carp	9.2	5.5	2.8	0.9		
Minnows	4.3		0.9	3.4		
Carpsuckers	0.4	0.3	0.02	0.1		
Suckers	3.5	2.8	0.2	0.5		
Hog suckers						
Buffalofishes	70.9	31.9	3.6	35.5		
Redhorses	0.4		0.4			

(Continued)

Appendix G (Continued)

Species or Species Group	Carrying Capacity	Detritus	Benthos	Zooplankton	Fish	Terrestrial
		Carrying Capacity Biomass in Pounds per Acre Supported by Each Food Compartment				
	Lower Mississippi Valley Drainage Area (Continued)					
Bullheads	0.4	0.1	0.2		0.1	
Catfishes	24.9		4.5		20.4	
Madtoms	0.2	0.1	0.1		0.04	
Silversides						
Temperate basses	1.0				1.0	
Sunfish	10.4	0.5	7.1		0.9	1.9
Black basses	15.5		1.2		13.3	0.9
Crappies	17.8	0.7	3.6	3.2	10.3	
Perches						
Freshwater drum	26.1	2.1	15.1		8.9	
All other species	0.1		0.1			
Total	253.1	103.4	42.9	43.6	60.4	2.8
	Blue Mountain, Nimrod, and Wister Reservoirs Drainage Area					
Gars	17.3				17.3	
Bowfin						
Gizzard shad	49.7	47.2	2.5			
Threadfin shad						
Pickerels						
Carp	39.2	23.5	11.7	3.9		
Minnows	1.1		0.2	0.9		
Carpsuckers						
Suckers	7.8	6.3	0.4	1.2		
Hog suckers						
Buffalofishes	264.2	118.9	13.2	132.1		
Redhorses						
Bullheads	0.3	0.1	0.2		0.1	
Catfishes	12.1		2.2		9.9	
Madtoms						
Silversides						
Temperate basses	6.0				6.0	
Sunfish	10.3	0.5	7.0		0.9	1.9
Black basses	16.6		1.3		14.3	1.0
Crappies	26.3	1.1	5.3	4.7	15.3	
Perches						
Freshwater drum	55.4	4.4	32.1		18.8	
All other species						
Total	506.3	201.9	76.1	142.8	82.6	2.9
	Arkansas River Basin Drainage Area*					
Gars	1.7				1.7	
Bowfin						
Gizzard shad	125.8	119.5	6.3			
Threadfin shad	1.3	0.9	0.4			
Pickerels						
Carp	58.0	34.8	17.4	5.8		

(Continued)

* Blue Mountain, Nimrod, Wister, and Great Salt Plains excluded.

Appendix G (Continued)

Species or Species Group	Carrying Capacity	Carrying Capacity Biomass in Pounds per Acre Supported by Each Food Compartment: Detritus	Benthos	Zooplankton	Fish	Terrestrial
	Arkansas River Basin Drainage Area (Continued)					
Minnows	0.4		0.1	0.3		
Carpsuckers	36.4	29.1	1.8	5.5		
Suckers						
Hog suckers						
Buffalofishes	86.1	38.8	4.3	43.1		
Redhorses	4.6		4.6			
Bullheads	3.7	1.0	2.1		0.7	
Catfishes	21.8		3.9		17.9	
Madtoms						
Silversides						
Temperate basses	8.3				8.3	
Sunfish	17.1	0.9	11.6		1.5	3.1
Black basses	13.5		1.1		11.6	0.8
Crappies	19.0	0.8	3.8	3.4	11.0	
Perches						
Freshwater drum	49.2	3.9	28.6		16.7	
All other species						
Total	446.9	229.6	85.9	58.0	69.5	3.9
		Red River Basin Drainage Area				
Gars	1.3				1.3	
Bowfin	0.6				0.6	
Gizzard shad	66.8	63.4	3.3			
Threadfin shad	6.8	4.7	2.0			
Pickerels	0.6				0.6	
Carp	8.2	4.9	2.5	0.8		
Minnows	1.2		0.2	1.0		
Carpsuckers						
Suckers	5.6	4.5	0.3	0.8		
Hog suckers						
Buffalofishes						
Redhorses	22.8		22.8			
Bullheads	0.6	0.2	0.4		0.1	
Catfishes	10.0		1.8		8.2	
Madtoms						
Silversides	0.1		0.03	0.1		
Temperate basses	3.0				3.0	
Sunfish	35.8	1.8	24.3		3.2	6.4
Black basses	17.5		1.4		15.1	1.1
Crappies	7.2	0.3	1.4	1.3	4.2	
Perches	0.5		0.1	0.1	0.3	
Freshwater drum	8.0	0.6	4.7		2.7	
All other species	0.1		0.1			
Total	196.7	80.4	65.3	4.1	39.3	7.5

(Continued)

Appendix G (Concluded)

Species or Species Group	Carrying Capacity	Carrying Capacity Biomass in Pounds per Acre Supported by Each Food Compartment: Detritus	Benthos	Zooplankton	Fish	Terrestrial
		White River Basin Drainage Area				
Gars	0.1				0.1	
Bowfin						
Gizzard shad	66.9	63.6	3.3			
Threadfin shad	7.0	4.9	2.1			
Pickerels						
Carp	10.8	6.5	3.2	1.1		
Minnows	0.7		0.1	0.6		
Carpsuckers	2.8	2.3	0.1	0.4		
Suckers	2.4	1.9	0.1	0.4		
Hog suckers						
Buffalofishes	27.8	12.5	1.4	13.9		
Redhorses	34.9		34.9			
Bullheads	0.8	0.2	0.5		0.2	
Catfishes	9.7		1.7		7.9	
Madtoms	0.2	0.1	0.1		0.04	
Silversides	0.4		0.1	0.3		
Temperate basses	3.5				3.5	
Sunfish	19.5	1.0	13.2		1.8	3.5
Black basses	14.1		1.1		12.1	0.8
Crappies	5.6	0.2	1.1	1.0	3.2	
Perches	1.5		0.3	0.3	0.9	
Freshwater drum	2.6	0.2	1.5		0.9	
All other species	0.3		0.3			
Total	211.4	93.3	65.3	17.9	30.6	4.3

APPENDIX H: ANNUAL FISH HARVEST

Appendix H: Part I

Annual Sport Fish Harvest

Drainage Areas	Area-Weighted Sport Fish Harvest	Area-Weighted Sport Fish Harvest Supported by Each Food Compartment*											
		Plant Material		Detritus		Benthos		Zooplankton		Fish		Terrestrial	
		lb/acre	% TH	lb/acre	% TH	lb/acre	% TH	lb/acre	% TH	lb/acre	% TH	lb/acre	% TH
Central and South Pacific	27.5	2.3	8.4	1.1	4.0	14.3	52.0	1.0	3.6	6.1	22.2	2.7	9.8
Central Valley	31.1	2.0	6.4	1.2	3.8	10.2	32.8	2.5	8.0	13.4	43.1	1.8	5.8
Columbia Basin	4.8	0.2	4.2	0.04	0.8	2.2	45.8	0.5	10.4	1.6	33.3	0.3	6.2
Great Basin	26.8	1.3	4.8			15.9	59.3	4.0	14.9	2.9	10.8	2.7	10.1
Colorado Basin	7.1	0.4	5.6	0.03	0.4	2.8	39.4	0.6	8.4	2.6	36.6	0.6	8.4
Missouri Basin	5.1	0.4	7.8	0.6	11.8	1.5	29.4	0.4	7.8	2.2	43.1	0.2	3.9
White River Basin	25.9	1.3	5.0	0.6	2.3	5.5	21.2	1.7	6.6	16.2	62.5	0.8	3.1
Arkansas River Basin	51.0	2.7	5.3	2.0	3.9	11.9	23.3	4.2	8.2	28.4	55.7	0.8	1.6
Red River Basin	32.1	1.6	5.0	1.1	3.4	10.9	34.0	1.7	5.3	14.9	46.4	1.9	5.9
Rio Grande and Gulf	57.5	2.6	4.5	2.2	3.8	13.1	22.8	3.4	5.9	33.9	59.0	2.1	3.6
Lower Mississippi	8.8	0.5	5.7	0.4	4.5	2.2	25.0	0.9	10.2	4.5	51.1	0.2	2.3
Upper Mississippi	12.7	2.1	16.5	2.5	19.7	3.5	27.6	0.8	6.3	3.2	25.2	0.2	1.6
Tennessee Valley	10.3	0.5	4.8	0.4	3.9	2.7	26.2	0.8	7.8	5.8	56.3	0.2	1.9
Ohio Basin	12.4	0.8	6.4	0.6	4.8	3.8	30.6	0.7	5.6	5.9	47.6	0.6	4.8
South - Gulf	11.7	0.6	5.1	0.4	3.4	3.0	25.6	0.8	6.8	6.3	50.8	0.5	4.3
South - Atlantic	7.6	0.3	3.9	0.2	2.6	1.6	21.0	0.6	7.9	4.7	61.8	0.2	2.6
Middle Atlantic	19.0	1.5	7.9	1.3	6.8	6.1	32.1	0.6	3.2	8.2	43.2	1.3	6.8
New England	2.5	0.1	4.0	0.045	1.8	0.8	32.0	0.2	8.0	1.3	52.0	0.1	4.0
Great Lakes and St. Lawrence	11.7	0.9	7.7	0.8	6.8	3.0	25.6	1.2	10.2	5.8	49.6	0.1	0.8
Area-Weighted Average	12.1	0.6	5.0	0.4	3.3	3.4	28.1	0.9	7.4	6.3	52.1	0.5	4.1

* TH = total harvest

Appendix H: Part II

Annual Commercial Fish Harvest

Drainage Area	Area-Weighted Harvest Supported by Each Food Compartment in Pounds Per Acre				
	Plant Material	Detritus	Benthos	Zooplankton	Fish
Colorado Basin	0.3	1.0	0.4	1.1	0.3
Missouri Basin	0.2	0.8	0.4	0.8	0.2
Upper Mississippi	2.5	9.1	4.4	10.1	2.9
Rio Grande and Gulf	0.3	1.0	0.5	1.1	0.3
Arkansas River Basin	0.4	1.3	0.6	1.4	0.4
Red River Basin	0.1	0.3	0.2	0.3	0.1
Tennessee Valley	1.3	4.6	2.2	5.1	1.4
Ohio Basin	0.3	1.1	0.5	1.2	0.3
Great Lakes and St. Lawrence	3.3	11.9	5.8	13.2	3.8
Area-Weighted Average	0.6	2.4	1.1	2.4	0.7

APPENDIX I: MAXIMUM SPECIFIC DAILY GROWTH RATES IN WEIGHT FOR RESERVOIR FISH SPECIES

Appendix I

Maximum Specific Daily Growth Rates in Weight for Reservoir Fish Species

Species	Age Class I	II	III	IV	V
Golden redhorse		0.00662	0.00274	0.00138	0.00130
Smallmouth buffalo		0.00250	0.00256	0.00139	0.00313
Bigmouth buffalo		0.00398	0.00289	0.000665	0.00144
Black buffalo		0.00190	0.00124	0.00171	
Carp		0.00560	0.00509	0.00245	0.00195
River carpsucker		0.00723	0.00377	0.00317	0.00270
Golden shiner		0.00344	0.000855	0.00103	0.000594
White sucker		0.00520	0.00255	0.00170	0.00212
Longnose sucker		0.00371	0.00207	0.00160	0.00156
Freshwater drum		0.00703	0.00342	0.00240	0.00181
Longnose gar		0.00177	0.000797	0.000652	0.000299
Paddlefish		0.00658			
Mountain whitefish				0.00282	0.00159
Round whitefish		0.00133	0.000856		
Brook trout	0.0213	0.0216*	0.00270	0.000707	
Lake trout		0.00190	0.00207	0.00173	0.00190
Brown trout		0.00727	0.00267	0.00283	0.00169
Rainbow trout		0.00683	0.00302	0.00171	0.000823
Cutthroat trout		0.00516	0.00234	0.00114	0.000734
Kokanee		0.00282	0.000593		0.000515
Largemouth bass	0.0291	0.00728	0.00344	0.00395	0.00283
Smallmouth bass	0.0183*	0.0121*	0.00451	0.00180	0.00251
Spotted bass		0.00287	0.00317	0.00166	0.000988
Green sunfish		0.00847	0.00679	0.00198	0.00145
Pumpkinseed	0.00349	0.00315	0.00163	0.00131	0.000716
Bluegill	0.00631	0.00681	0.00527	0.00333	0.00232
Redear sunfish		0.00533	0.00360	0.00294	0.00199
Spotted sunfish		0.00713			
Warmouth		0.00742	0.00414	0.00246	0.00169
Rock bass	0.00644	0.00537	0.00210	0.00156	0.00130
White crappie		0.00226	0.00263	0.00237	0.00206
Black crappie		0.00669	0.00408	0.00180	0.00145
White bass		0.00812	0.00380	0.000967	0.00245
Yellow perch		0.00494	0.000821	0.00133	0.00109
Walleye		0.00351	0.00190	0.00135	0.000902
Sauger		0.000715	0.00293	0.000945	0.000522
Chain pickerel		0.00303	0.00190	0.00262	0.00114
Northern pike		0.00684	0.00301	0.00411	0.00174
Channel catfish	0.0213	0.00853	0.00489	0.00184	0.00434
Flathead catfish		0.00913	0.00478	0.00291	0.00275

* Laboratory studies over limited time periods. All other data are from field studies and represent the maximum values reported in the literature.

Appendix I (Concluded)

Species	Age Class I	II	III	IV	V
Blue catfish	0.00558	0.00377	0.00262	0.00140	0.00179
Yellow bullhead		0.00703	0.000913	0.000614	0.000509
Brown bullhead			0.000857		
Black bullhead		0.00522	0.00685	0.00350	0.00304
Silver redhorse		0.00496	0.00260	0.00188	0.00123
Northern redhorse		0.00560	0.00223	0.00440	0.000493

APPENDIX J: DIGESTIVE EFFICIENCIES AND FOOD CONSUMPTION OF FISH

Appendix J

Digestive Efficiencies and Food Consumption of Fish

Species	Study Location	Age, length, or weight	Assimilation Efficiency	Ecological Growth Efficiency	Daily Meal as % Body Weight	Comments	Reference
Largemouth bass	?	fingerling to 454 g			4.0=optimum level	Water temp.=21.1°C.	Thompson (1941)
Largemouth bass	Concrete ponds, AL	20-255 g		24.1		Fed on fish. Water temp.=26.7-32.2°C. Jun-Sep.	Prather (1950)
Largemouth bass	Laboratory	71-115 g, $\bar{x}$=89 g			7.01	Fed on mosquitofish or mollies. Water temp.=24-25°C.	Hunt (1960)
Largemouth bass	Laboratory		95.7 for protein N. 95.5 for lipid. 89.6 for energy.				Beamish (1972)
Largemouth bass	Laboratory	22 g 464 g		31.2 15.2	5.4 2.0	Water temp.=19.4-25.0°C, $\bar{x}$=21.3°C. Fed on minnows.	Williams (1959)
Largemouth bass	Crab Orchard Lake, IL	90-450 g 451-900 g 901-1350 g 1351-1800 g 1800+ g			4.0 3.5 3.5 1.6 1.5	Apr-Oct	Lewis et al. (1974)
Smallmouth bass	?	7.5 g 27.4 g 39.5 g 57.0 g 111.5 g		30.7 21.4 19.3 27.2 22.8	9.4 3.2 2.8 2.8 3.0	Water temp.=19.4-25.0°C, $\bar{x}$=21.3°C. Fed on minnows.	Williams (1959)
Rock bass	Lake Opinicon, Ontario, Canada	29-90 g			2-4	Jun	Keast and Welsh (1968)
White bass	Lake Mendota, WI and Laboratory	44-77 mm	66.0-69.2, $\bar{x}$=67.35	17.3-35.3, $\bar{x}$=27.25		Annual cycle	Wissing (1974)
Bluegill	Laboratory	20.2-148.5 g	80.0 @ 15°C 79.9 @ 20°C 80.0 @ 25°C	44 @ 15°C 33 @ 20°C 30 @ 25°C	1.97 @ 15°C 1.88 @ 20°C 2.94 @ 25°C	16-hr. photoperiod.	Pierce and Wissing (1974)
Bluegill	Maple and Grove Lakes, MN	100-211 mm 27-114 g			Maple Lake: 2.04 @ 27 g 2.2 @ 55 g 1.84 @ 114 g Grove Lake: 1.67 @ 64 g 1.38 @ 95 g	Avg. water temp.= 22.2°C. Summer.	Seaburg and Moyle (1964)

(Continued)

Appendix J (Continued)

Species	Study Location	Age, length, or weight	Assimilation Efficiency	Ecological Growth Efficiency	Daily Meal as % Body Weight	Comments	Reference
Bluegill	Laboratory	29.7 g	97.2 (protein absorption)	32=Maximum protein utilization for growth.	1.00=maintenance. 3.5=maximum intake.	Avg. water temp.= 24.6°C.	Gerking (1955)
Bluegill	White Oak Lake, TN	III, IV		4.2=Apr-Oct	0.8-3.2, $\bar{x}$=1.75	Jun-Jan	Kolehmainen (1974)
Bluegill	Wyland Lake, IN	II-V 14-35 g		17.2 for protein.	3.6 in Lab.	Avg. water temp.= 23.9°C. Data are a revision of Gerking (1962). Summer.	Gerking (1972)
Bluegill	Lake Opinicon, Ontario, Canada	11.1-58 g			2-4	Jun	Keast and Welsh (1968)
Carp	Laboratory		74	31		Fed on Chironimids.	Ivlev (1939)
Carp	White Oak Lake, TN	I-VII		8.0	3.9	Annual cycle.	Kevern (1966)
Carp			95			Data in doubt.	Kobashi and Deguchi (1971)
Blue catfish	Laboratory	3.78 g 8.69 g		35.5		20°C, 16-hr. photoperiod.	Tyler and Kilambi (1973)
Channel catfish	Laboratory	5.5 g 23 g		62.5 62.5		12-hr. photoperiod.	Stickney and Andrews (1971)
Channel catfish	Laboratory	4 g		55.6 @ 22°C 41.7 @ 18°C 52.6 @ 26°C 16.7 @ 18°C 33.3 @ 22°C 30 @ 26°C 9.4 @ 18°C 18.2 @ 22°C 28.6 @ 26°C	2 2 2 4 4 4 6 6 6		Andrews and Stickney (1972)
Channel catfish	Laboratory			9.56		32°C=optimum temperature for food conversion. 14-hr. photoperiod @ 32°C.	Kilambi et al. (1970)
Black crappie	Maple and Grove Lakes, MN	122-368 mm			Maple Lake: 2.12 @ 64 g 2.00 @ 104 g 1.58 @ 190 g	Avg. water temp.= 22.2°C. Summer.	Seaburg and Moyle (1964)

(Continued)

Appendix J (Continued)

Species	Study Location	Age, length, or weight	Assimilation Efficiency	Ecological Growth Efficiency	Daily Meal as % Body Weight	Comments	Reference
Black crappie (Con't)	Maple and Grove Lakes, MN (Con't)				Grove Lake: 2.00 @ 32 g 1.00 @ 100 g 0.58 @ 159 g		
Florida gar	Laboratory	70-132 g, $\bar{x}$=110 g 30, 35 g			2.81 4.26	Fed mosquitofish or mollies. Water Temp. 24-25°C.	Hunt (1960)
Longnose gar	Missouri creeks and rivers, and Laboratory	6.00 g 13.88 g 24.69 g 33.49 g $\bar{x}$=20.96 g		64.0 49.5 40.9 34.7 $\bar{x}$=43.1	10.1 11.3 7.3 8.0 $\bar{x}$=9.1	Water temp.-26.4°C.	Netsch and Witt (1962)
Goldfish	Laboratory		71.5-86.5			At maintenance level @ 21.5°C.	Davies (1964)
Blueback herring	James River, VA and Laboratory	1.16-3.97 g	80.0	9.3		Water temp.=16.4-28.7°C. Constant light. Jun-Nov.	Burbidge (1974)
Muskellunge	Laboratory	17 g		36.7	6.4	Water temp.=17-22°C, $\bar{x}$=19.5°C. Fed on minnows. 12-hr photoperiod.	Gammon (1963)
Yellow perch	Lake Opinicon, Ontario, Canada	7.8-26.5 g			2-4	Jun	Keast and Welsh (1968)
Northern pike	Lake Windemere, Great Britain	150 g	72	30		Data in doubt. Fed minnows. Annual cycle.	Johnson (1966)
Northern pike	Laboratory				5.0	Fed minnows and insects	Mongeau (1954, 1955)
Pumpkinseed	Lake Opinicon, Ontario, Canada	18-62 g				Jun	Keast and Welsh (1968)
Pumpkinseed	Maple and Grove Lakes, MN	100-179 mm 36-114 g			Maple Lake: 1.38 @ 36 g 1.03 @ 68 g 1.0 @ 127 g Grove Lake: 1.13 @ 77 g 0.61 @ 114 g	Summer. Avg. water temp.=22.2°C.	Seaburg and Moyle (1964)

(Continued)

Appendix J (Continued)

Species	Study Location	Age, length, or weight	Assimilation Efficiency	Ecological Growth Efficiency	Daily Meal as % Body Weight	Comments	Reference
Sockeye salmon	Laboratory	Fingerlings		$\bar{x}$=20, maximum=25	Y=0.542 + 0.308X. X=temp. °C. =5.2 @ 15°C.	Optimum temp.=15°C. Spring-Fall.	Brett et al. (1969)
Sockeye salmon	Laboratory	Young			1.5-11.3 for fingerlings. $\bar{x}$=5 1.5-7.6 for yearlings.	Annual consumption amounts to 8-9 times final weight, which is typical of plantivores.	Krokhin (1959)
Brown trout	Laboratory	40.7 g 85.2 g		12.9 12.0		Fed on *Gammarus*.	Pentelow (1939)
Cutthroat trout	Laboratory	Under-yearling	84.9-86.1, $\bar{x}$=85.5	5.2-11.8 in the field.		10°C minimum assimilation efficiency.	Brocksen (1966)
Walleye	Laboratory	160-205 g, II-VI	E_2=96.851-0.0045W; r=0.824	14.3 @ 20°C	4.0=optimum	Fed on age 0 perch.	Kelso (1972)
			E_2=82.103-0.0041W; r=0.859	12.7 @ 16°C		Fed on amphipods.	
			E=83.535-0.0045W	11.3 @ 8-16°C		Fed on crayfish.	
			E=97.871-0.0045W	13.9 @ 12°C		Fed on emerald shiner. W=weight (g), E=assimilation efficiency. 14-hr photoperiod.	
Walleye and Sauger	Lake of the Woods, Ontario, Canada	III, IV		16.9 for Jun. 20 for other months.	1.0 in Jun, 2.0 in Jul, 3.0 in Aug-Sep.	Jun-Sep	Swenson and Smith (1973)
Warmouth	Laboratory	72-113 g, $\bar{x}$=93 g			4.37	Fed on mosquitofish or mollies. Water temp.=24-25°C.	Hunt (1960)
Reticulate sculpin	Laboratory	fearling	78.4-84.4, $\bar{x}$=81.9	38.6=optimum @ 8.3-15.0°C.		10°C minimum assimilation efficiency.	Davis and Warren (1965)
Stickleback	Laboratory	Adult			1.8-5.1, $\bar{x}$=2.7		Krokhin (1959)

(Continued)

Species	Study Location	Age, length, or weight	Assimilation Efficiency	Ecological Growth Efficiency	Daily Meal as % Body Weight	Comments	Reference
Green sunfish	Laboratory	II-IV or 68-110 mm		28		Avg. water temp.= 24.7°C. Jul-Aug	Gross et al. (1965)
Green sunfish	Laboratory	7.1-48.5 g max. age=IV	92.3 (nitrogen absorption) 95.7 (protein absorption)	38.7 for 7.1 g wet wt. (1.59 g dry wt.)=gross protein utilization for growth. 32.6 for 11.2 g wet (2.18 dry). 29.8 for 18.2 g wet (3.54 dry). 19.2 for 48.5 g wet (12.37 dry).		Avg. water temp.= 24.5-25.5°C. Fed mealworms.	Gerking (1952a)
Longear sunfish	Laboratory	9.1-103.3 g max. age=VI	94.0 (nitrogen absorption) 97.4 (protein absorption)	32 for 9.1 g wet wt. (2.56 dry wt.)=gross protein utilization for growth. 27.8 for 23.6 g wet (6.64 dry). 29.4 for 28.2 g wet (7.92 dry). 23.4 for 57.9 g wet (17.19 dry). 4.6 for 103.3 g wet (30.68 dry).		Avg. water temp.= 24.5-25.5°C. Fed mealworms.	Gerking (1952a)
Brook trout Brown trout Rainbow trout	Hatchery	98-240 mm			6.0 for 98-122 mm fish. 2.0 for 220-240 mm fish.	Max. allowances for growth @ 15.6°C.	Third Ed. N.Y. State Hatchery Feeding Chart (1952)
Cichlasoma bimaculatum	Laboratory		82.8 @ 20°C 84.0 @ 24°C 88.6 @ 28°C 85.6 @ 32°C 69.6 @ 36°C	33.7 44.0 51.7 43.4 14.5		Fed on *Tubifex*.	Warren and Davis (1967)

(Continued)

Appendix J (Concluded)

Species	Study Location	Age, length, or weight	Assimilation Efficiency	Ecological Growth Efficiency	Daily Meal as % Body Weight	Comments	Reference
Roach	Laboratory and River	21.2 g	78.9	5.5		Egestion and excre-	Mann (1965)
Bleak	Thames, Great Britain	34.3 g	79.5	6.6		tion assumed to be	
Dace		2.8 g	79.4	4.1		20% of food intake.	
Perch		3.1 g	79.2	4.8		Seasonal temperature	
Gudgeon		4.5 g	79.4	4.6		fluctuations. Annual	
$\bar{x}$			79.4	6.0		cycle.	
Plaice	Laboratory	Young		20			Colman (1970)
Bleak	Laboratory	Young	69.9	19.6		Water temp. 20°C. Egestion=30.1%.	Ivlev (1961)
Carnivorous fish			80	20		General budget based on review of various results up to 1956.	Winberg (1956)

APPENDIX K: ANNUAL, DAILY, AND INSTANTANEOUS NATURAL MORTALITY RATES FOR VARIOUS FISH SPECIES

Appendix K

Annual, Daily, and Instantaneous Natural Mortality Rates for Various Fish Species

Species	Study Location	Age or Length	Annual Natural Mortality Rate	Daily Natural Mortality Rate	Instantaneous Natural Mortality Rate	Comments	Reference
Largemouth bass	Browns Lake, WI		≈0.136	0.00037			Mraz and Threinen (1955)
	Gordy Lake, IN	≥V	≈0.24	0.00066		Poor sample.	Gerking (1952b)
	Beaver Reservoir, AR	All ages	0.437-0.716	0.0015	0.575-1.259	1968-1975	Houser (unpublished)
Rock bass	Nebish Lake, WI	X-XI	0.66	0.0018		Unexploited population	Ricker (1947)
		XI-XII	0.71	0.0019			
		XII-XIII	0.78	0.0021			
		XIII-XIV	0.79	0.0022			
Bluegill	Lodge Lake, MI	≥4.0"	0.8519	0.0023	1.91		Patriarche (1968)
	Jewett Lake, MI	≥4.0"	0.7961	0.0022	1.59	% dist. of natural mort.: 7 (spring), 81 (summer), 12 (fall), 0 (winter).	Patriarche (1968)
	Gordy Lake, IN	≥IV	≈0.47	0.0013			Gerking (1952b)
	Muskellunge Lake, IN (1942-43)		≈0.49	0.0013			Ricker (1945)
	Shoe Lake, IN (1941-42)		≈0.57	0.0016			Ricker (1945)
	Shoe Lake, IN (1942-43)		≈0.59	0.0016			Ricker (1945)
	Wawasee Lake, IN		≈0.68	0.0019		20% est. exploitation rate.	Ricker (1945)
	Gordy Lake, IN	II-III	0.38	0.0010	0.481		Gerking (1952b)
		III-IX	0.49	0.0013	0.667		
Brown bullhead	Clear Lake, CA		0.17	0.00047			McCammon and Seeley (1961)
	Folsom Lake, CA		0.34	0.00093			Rawstron (1967)
Channel catfish			0.314	0.00086	0.376		Ricker (1958)
White catfish	Clear Lake, CA		0.19	0.00052	0.21		McCammon and Seeley (1961)
	Folsom Lake, CA		0.57	0.0016			Rawstron (1967)
Freshwater drum	Mississippi River		0.257	0.00070			Butler (1965)
Northern pike	Ball Club Lake, MN	III-VIII	0.60	0.0016			Johnson and Peterson (1955)
	Lake in MN	III-VIII	0.769	0.0021			Groebner (1960)
	Lake in MN	III-VIII	0.708	0.0019			Groebner (1960)
	MN		0.497	0.0014			Scidmore (1955)
Sauger	Lake Nipigon, Ontario, Canada	VIII-IX	0.23?	0.00063		Unexploited population	Ricker (1947)
		IX-X	0.26	0.00071			
		X-XI	0.30	0.00082			
		XI-XII	0.34	0.00093			
		XII-XIII	0.47	0.0013			
		XIII-XIV	0.60	0.0016			

(Continued)

Appendix K (Concluded)

Species	Study Location	Age or Length	Annual Natural Mortality Rate	Daily Natural Mortality Rate	Instantaneous Natural Mortality Rate	Comments	Reference
American shad	Connecticut River		0.73	0.0020			Walburg (1961)
Longnose sucker	Great Slave Lake, Northwest Territories, Canada	>XI	0.55	0.0015			Geen et al. (1966); Harris (1962); Harris (1952)
Redear sunfish	Gordy Lake, IN	≥IV	≈ 0.40	0.0011			Gerking (1952b)
Brook trout	Pigeon River, MI				0.012	Spring-Summer	Latta (1962)
	East Fish Lake, MI				0.003-0.004		Alexander and Shetter (1961)
	New York Lakes				1.34	Summer average	Hatch and Webster (1961)
	Lawrence Creek, WI				0.56	Winter average	Hatch and Webster (1961)
	Ford and Hemlock Lakes, MI				0.75-0.96		McFadden (1961)
Cutthroat trout			0.16-0.75	0.00044-0.0021			Hansen (1971)
	Yellowstone Lake, WY		0.614	0.0017			Ball and Cope (1961); Welsh (1952)
Rainbow trout	Finger Lakes, NY		0.66	0.0018	1.08		Hartman (1959)
Walleye	Many Points Lake, MN	I-VII	0.0479	0.00013	0.0491		Olson (1957)
Whitefish	Lake Opeongo, Ontario, Canada	VI-VII	0.41			Unexploited population	Ricker (1947)
		VII-VIII	0.46				
		VIII-IX	0.48				
		IX-X	0.51				
		X-XI	0.56				
		XI-XII	0.56				
		XII-XIII	0.59				
	Shakespeare Island Lake, Ontario, Canada	XI-XII	0.08			Unexploited population	Ricker (1947)
		XII-XIII	0.09				
		XIII-XIV	0.10				
		XIV-XV	0.11				
		XV-XVI	0.11				
		XVI-XVII	0.12				
		XVII-XVIII	0.13				
		XVIII-XIX	0.15			Unexploited population	Ricker (1947)
		XIX-XX	0.17				
		XX-XXI	0.21				
		XXI-XXII	0.24				
		XXII-XXIII	0.27				
		XXIII-XXIV	0.32				
		XXIV-XXV	0.36				
		XXV-XXVI	0.40				
		XXVI-XXVII	0.45				
	Georgian Bay of Lake Huron, Ontario, Canada	>III	0.41				Cucin and Regier (1965)

APPENDIX L: METABOLIC RATES OF FISH

Appendix L: Part I

Regression Equations Relating Active Metabolism at Various Temperatures to Fish Weight

Species	Temperature, ^{o}C	Regression Equation*	Reference
Brook trout	5	$\log Y = -0.730 + 0.942 \log W$	Job (1955)
	10	$\log Y = -0.461 + 0.862 \log W$	
	15	$\log Y = -0.391 + 0.851 \log W$	
	20	$\log Y = -0.075 + 0.750 \log W$	
Sockeye salmon	15	$\log Y = -0.050 + 0.970 \log X$	Brett (1965)

* Y = metabolic rate (mgO_2/hr)
W =
X = weight (g)

Appendix L: Part II

Regression Equations Relating Standard Metabolism at Various Temperatures to Fish Weight

Species	Temperature, °C	Regression Equation*	Reference
Goldfish	10	$\log Y = -1.568 + 0.882 \log X$	Beamish and Mookherjii (1964)
	20	$\log Y = -0.348 + 0.913 \log X$	
	30	$\log Y = -0.577 + 0.717 \log X$	
	35	$\log Y = -0.670 + 0.887 \log X$	
Carp	10	$\log Y = -1.735 + 0.983 \log X$	Beamish (1964a)
	20	$\log Y = -1.137 + 0.909 \log X$	
	30	$\log Y = -0.733 + 0.876 \log X$	
	35	$\log Y = -0.550 + 0.810 \log X$	
Brown bullhead	10	$\log Y = -1.696 + 0.998 \log X$	Beamish (1964a)
	20	$\log Y = -0.986 + 0.903 \log X$	
	30	$\log Y = -0.721 + 0.874 \log X$	
White sucker	10	$\log Y = -1.460 + 0.994 \log X$	Beamish (1964a)
	15	$\log Y = -0.772 + 0.828 \log X$	
	20	$\log Y = -0.497 + 0.770 \log X$	
Brook trout	10	$\log Y = -1.476 + 1.107 \log X$	Beamish (1964a)
	15	$\log Y = -0.996 + 1.014 \log X$	
	20	$\log Y = -0.905 + 1.036 \log X$	
Brown trout	10	$\log Y = -0.847 + 0.877 \log X$	Beamish (1964a)
Sockeye salmon	15	$\log Y = -0.632 + 0.775 \log X$	Brett (1965)

* Y = metabolic rate (mgO_2/hr)
X = weight (g)

Appendix L: Part III

Summary of Fish Metabolic Rates at Various Temperatures, Ages, and Weights

				Oxygen Consumption, $ml O_2/g/hr$								
Species	Age	Wet Weight, g	Temperature, °C	Standard	1/4 Active	1/2 Active	3/4 Active	Routine	Full Active	Active/ Standard	Routine/ Standard	Reference
Sockeye salmon	Yearling	36.7	5	0.0287					0.360	12.5		Brett (1964)
	Yearling	32.9	10	0.0420					0.439	10.5		
	Yearling	55.2	15	0.0497	0.0924	0.175	0.336		0.627	12.6		
	Yearling	62.9	20	0.0840					0.596	7.1		
	Yearling	52.2	24	0.137					0.594	4.3		
	Underyearling	3.38	15	0.161	0.231	0.322	0.462		0.644	4.0		Brett (1965)
	Underyearling	8.47	15	0.0770	0.130	0.210	0.361		0.581	7.5		
	Underyearling	19.1	15	0.0889					0.490	5.5		
	Adult (jacks)	746	15	0.0497	0.882	0.158	0.287		0.511	10.3		
	Adult	1432	15	0.308	0.0616	0.123	0.245		0.502	16.3		
Brook trout		?	5	0.0240*								Graham (1949)
		?	5	0.0259*								Flörke et al. (1954)
		15	5	0.0867*								Job (1955)
		164	10	0.0480*					0.217	4.5		Graham (1949)
		164	10						0.224*			Basu (1959)
		?	10	0.0434*								Flörke et al. (1954)
		15	10	0.153*								Job (1955)
		100	10	0.0555				0.0926			1.7	Beamish (1964a)
		100	15	0.0750				0.159			2.1	
		164	15	0.0800*					0.343	4.3		Graham (1949)
		164	15						0.343*			Basu (1959)
		?	15	0.0700*								Flörke et al. (1954)
		15	15	0.227*								Job (1955)
		15	20	0.287*								
		100	20	0.103*				0.152			1.5	Beamish (1964a)
		?	20	0.091*								Flörke et al. (1954)
		164	20	0.110*					0.245	2.2		Graham (1949)
		164	20						0.210*			Basu (1959)
		?	25	0.150*								Graham (1949)
Rainbow trout			5	0.0420*								Flörke et al. (1954)
			10	0.0700*								
			15	0.105*								
			20	0.140*								
Brown trout		100	10	0.0566								Beamish (1964a)

* Determined from a graph.

Appendix L: Part III (Continued)

Species	Age	Wet Weight, g	Temperature, °C	Oxygen Consumption, $mlO_2/g/hr$ Standard	1/4 Active	1/2 Active	3/4 Active	Routine	Full Active	Active/ Standard	Routine/ Standard	Reference
Lake trout	Age I	27.7	10	0.0350*					0.190	5.4		Gibson and Fry (1954)
		27.7	15	0.0600*					0.300	5.0		
		27.7	20	0.900*					0.280	3.1		
	Age II	82.8	10	0.0250*					0.205	8.2		
		82.8	15	0.0400*					0.265	6.6		
		82.8	20	0.0650*					0.265	4.1		
White sucker		100	10	0.0243				0.0572			2.4	Beamish (1964a)
		100	15	0.0550				0.0725			1.3	
		100	20	0.0773				0.0962			1.2	
Brown bullhead		15	5	0.0252*					0.0630	2.5		Fry (1947)
		15	10	0.0504*					0.147	2.9		
		15	15	0.105*					0.231	2.2		
		15	20	0.168*					0.378	2.3		
		15	25	0.273*					0.567	2.1		
		15	30	0.357*					0.756	2.1		
		15	35	0.399*					0.945	2.4		
		100	10	0.0140				0.0371			2.7	Beamish (1964a)
		100	20	0.0463				0.0680			1.5	
		100	30	0.0743				0.0946			1.3	
Carp		100	10	0.0119								Beamish (1964a)
		100	20	0.0336				0.0791			2.4	
		104	20						0.476*			Basu (1959)
		100	30	0.0732				0.140			1.9	Beamish (1964a)
		104	30						0.630*			Basu (1959)
		100	35	0.0821								Beamish (1964a)
Goldfish		3.8	5	0.0150*					0.0280	1.9		Fry and Hart (1948)
		3.8	10	0.0250*					0.0600	2.4		
		74	10						0.196*			Basu (1959)
		100	10	0.0110								Beamish and Mookherjii (1964)
		100	15	0.0140								
		3.8	15	0.0550*					0.115	2.1		Fry and Hart (1948)
		3.8	20	0.0800*					0.155	1.9		
		74	20						0.245*			Basu (1959)
		100	20	0.0211								Beamish and Mookherjii (1964)
		100	25	0.0315								
		3.8	25	0.145*					0.260	1.8		Fry and Hart (1948)
		3.8	30	0.175*					0.295	1.7		
		74	30						0.350*			Basu (1959)
		100	30	0.0504								Beamish and Mookherjii (1964)
		100	35	0.0889								

(Continued)

Appendix L: Part III (Concluded)

Species	Age	Wet Weight, g	Temperature, °C	Oxygen Consumption, mlO_2/g/hr Standard	1/4 Active	1/2 Active	3/4 Active	Routine	Full Active	Active/ Standard	Routine/ Standard	Reference
Goldfish (Cont.)		3.8	35	0.220*					0.295	1.3		Fry and Hart (1948)
		32	23-25	0.0750*					0.328	4.4		Spoor (1946)
Yellow perch		?	5	0.0126*								Flörke et al. (1954)
		?	10	0.0259*								
		?	15	0.0420*								
		?	20	0.0700*								
		?	25	0.0980*								
Fish in general								**			1.7	Winberg (1956)

** See tables by Winberg (1956)

Appendix L: Part IV

Summary of Fish Metabolic Rates at 20°C*

Species	Wet Weight, g	Respiration, $ml O_2/g/hr$			Reference
		Standard	Routine	Active	
Sockeye salmon	62.9	0.0840		0.596	Brett (1964)
Brook trout	100	0.103	0.152		Beamish (1964b)
	?	0.091			Flörke et al. (1954)
	164			0.210	Basu (1959)
Rainbow trout	?	0.140			Flörke et al. (1954)
Lake trout	27.7	0.0900		0.281	Gibson and Fry (1954)
	82.8	0.0650		0.265	
White sucker	100	0.0773	0.0962		Beamish (1964b)
Brown bullhead	15	0.168		0.378	Fry (1947)
	100	0.0463	0.0680		Beamish (1964b)
Carp	100	0.0336	0.0791		
	104			0.476	Basu (1959)
Goldfish	3.8	0.0800		0.155	Fry and Hart (1948)
	74			0.245	Basu (1959)
	100	0.0211			Beamish and Mookherjii (1964)
Yellow perch	?	0.0700			Florke et al. (1954)
Generalized reservoir fish (estimated values)	100	0.0500	0.150	0.300	

* For additional data see Winberg (1956).

APPENDIX M: FISH TEMPERATURE TOLERANCES

Appendix M: Part I

Temperature Tolerance and Preference Data for Various Fish Species

Species	Age or Length	Acclimation Temperature	T_1 Lower Lethal Temperature	Best Temperature Range for Growth T_2	Optimum or (Preferred)	T_3	T_4 Upper Lethal Temperature	Comments	Reference
Gizzard shad		25	10.8				34.3		Hart (1952)
		30	14.5				35.9		
Carp		26					35.7	24-hr TL50	Black (1953)
Common shiner		5					26.7		Hart (1947)
		10					28.6		
		15	0.0				30.3		
		20	3.7						
		25	7.8				31.0		
		30					31.0		
Common shiner	Adult	5					26.7		Hart (1952)
		10					28.6		
		15					30.3		
		20					31.0		
		25					31.0		
Golden shiner		22.0					≈ 40		Alpaugh (1972)
Golden shiner	Adult	10					29.5		Hart (1952)
		15					30.5		
		20					32.0		
		25					33.5		
		30					34.5		
Emerald shiner					27				McCormick and Mischuk (1973)
Emerald shiner		5					23.2		Hart (1947)
		10					26.7		
		15	1.6				28.9		
		20	5.2				30.7		
		25	8.0				30.7		
Duskystripe shiner		21.5					32.0	Ultimate upper incipient lethal.	Hickman and Dewey (1973)
Bluntnose minnow		5					26.0		Hart (1947)
		10					28.3		
		15	1.0				30.6		
		20	4.2				31.7		
		25	7.5				33.3		

* All temperatures in °C.

Appendix M: Part I (Continued)

Species	Age or Length	Acclimation Temperature	T_1 Lower Lethal Temperature	Best Temperature Range for Growth T_2	Optimum or (Preferred)	T_3	T_4 Upper Lethal Temperature	Comments	Reference
Flathead minnow		10					28.2		Hart (1947)
		20	1.5				31.7		
		30	10.5				33.2		
Creek chub		5					24.7		Hart (1952)
		10					27.3		
		15					29.3		
		20	0.7				30.3		
		25	4.5				30.3		
Chub		14					27.1	24 hr TL50	Black (1953)
Finescaled sucker		14					26.9	24 hr TL50	Black (1953)
White sucker		25					31.2		Brett (1944)
White sucker	Adult	5					26.3		Hart (1947)
	I-II	10					27.7		
		15					29.3		
		20	2.5				29.3		
		25	6.0				29.3		
White sucker					27				McCormick (1973)
Brown bullhead		5					27.8		Hart (1952)
		10					29.0		
		15					31.0		
		20					32.5		
		25					33.8		
		30					34.8		
		34					34.8		
Brown bullhead		5					28.6		Brett (1944)
		10					30.2		
		15					31.8		
		20	-1.0				33.4		
		25	1.3				35.0		
		30	3.7				36.5		
Black bullhead		23					35		Black (1953)
Channel catfish	Yearling	25					35.5		Allen and Strawn (1968)
		35					38.0		
Channel catfish	Fingerling			18	30	34			Andrews and Stickney (1972)

(Continued)

Appendix M: Part I (Continued)

Species	Age or Length	Acclimation Temperature	T_1 Lower Lethal Temperature	T_2	Best Temperature Range for Growth: Optimum or (Preferred)	T_3	T_4 Upper Lethal Temperature	Comments	Reference
Channel catfish		15	0.0				30.3		Hart (1952)
		20	2.5				32.8		
		25	6.0				33.5		
Bluegill		21.5					35.5		Hickman and Dewey (1973)
Bluegill	Adult	15	2.5				30.7		Hart (1952)
		20	5.0				31.5		
		25	7.5						
		30	11.1?				33.8?		
Bluegill	Juvenile	12.1	3.2				27.5	96-hr TL 50	Banner and Van Arman (1973)
		32.9	15.3				37.3	96-hr TL 50	
Bluegill	II				22				McComish (1971)
Longear sunfish	Juvenile	25					35.6		Neill et al. (1966)
		30					36.8		
		35					37.5		
Pumpkinseed		25					24.5		Brett (1944)
Smallmouth bass	Juvenile	16-35	1.6 @ 35 10.1 @ 26		26.3		35.0	96-hr TL 50 (median tolerance limit)	Horning and Pearson (1973)
Smallmouth bass					28.3				Peck (1965)
Largemouth bass	Fry	15-30			27.5 and 30.0				Strawn (1961)
Largemouth bass		18-30			25				Niimi and Beamish (1974)
Largemouth bass		20	5.5				32.5		Hart (1952)
		25					34.5		
		30	11.8				36.4		
Black crappie		29			22-25		32.5		Hokanson and Kleiner (unpublished)
Yellow perch		5					21.3		Hart (1947)
		10	1.1				25.0		
		15					27.7		
		25	3.7				29.7		
Yellow perch		25					30.9		Brett (1944)
Yellow perch	Juvenile	24		20.0		23.3			McCauley and Read (1973)
	Adult	24		17.6		20.1			

(Continued)

Appendix M: Part I (Continued)

Species	Age or Length	Acclimation Temperature	T_1 Lower Lethal Temperature	Best Temperature Range for Growth T_2	Optimum or (Preferred)	T_3	T_4 Upper Lethal Temperature	Comments	Reference
Yellow perch	Fingerling	8			(18.6)				Ferguson (1958)
		10			(19.3)				
		15			(23.0)				
		20			(23.1)				
		25			(24.5)				
		30			(26.7)				
European perch							30-31	Independent of acclimation temperature	Weatherley (1963)
Sockeye salmon	Fry	5	0				22.2		Brett (1952)
		10	3.1				23.4		
		15	4.1				24.4		
		20	4.7				24.8		
Sockeye salmon	Juvenile	15		5	15	17			Brett et al. (1969)
Coho salmon	Fry	5	0.2				22.9		Brett (1952)
		10	1.7				23.7		
		15	3.5				24.3		
		20	4.5				25.0		
Chinook salmon	Fry				18.4				Olson and Foster (1955)
Northern pike	Larvae	17.7	3.2		26		28.4		Hokanson et al. (1973)
Northern pike	Juvenile	25					32.25		Scott (1964)
		27.5					32.75		
		30					33.25		
Lake trout	Yearling				(11.7)			Independent of acclimation temperature	McCauley and Tait (1970)
Lake trout				4(8)		(10) 18		Lake Louisa, Ontario, Canada	Martin (1952)
Lake trout				4(7)		(13) 18		Cayuga Lake, NY	Galligan (1962)
Lake trout				8		10.9		Lac la Ronge, Saskatchewan, Canada	Rawson (1961)
Lake trout				10		13		Moosehead Lake, MA	Cooper and Fuller (1945)
Lake trout	I-II	8, 15, 20			16.5		22.7, 23.5, 23.5		Gibson and Fry (1954)

(Continued)

Appendix M: Part I (Concluded)

Species	Age or Length	Acclimation Temperature	T_1 Lower Lethal Temperature	Best Temperature Range for Growth T_2	Optimum or (Preferred)	T_3	T_4 Upper Lethal Temperature	Comments	Reference
Rainbow trout	Juvenile	18					26.5		Alabaster and Welcomme (1962)
Rainbow trout	Under-yearling 4-5 cm	15-20		17	(18.4)	20			McCauley and Pond (1971)
Brook trout		5 10 15 20 25	 0.5				23.7 24.4 25.0 25.3 25.3		Fry et al. (1946)
Brook trout					13				Baldwin (1957)
Brook trout				14	16	19			Graham (1949)
Brook trout					15.4				McCormick et al. (1972)
Brown trout	Young				15.6				Pentelow (1939)
Brown trout					15.4				Wingfield (1940)
Brown trout					7-9 and 16-19				Brown (1946)
Brown trout					8-17, $\bar{x}$=125				Brett (1970)
Brown trout	Juvenile	5, 10, 20					22.2, 23.4, 23.5		Bishai (1960)
Mosquitofish		15 20 25 30	1.5 5.5				35.4 37.3 37.3 37.3		Hart (1952)
Goldfish		5 10 15 20 25 30	 2.0 6.0 9.0				29.0 30.8 32.8 34.8 36.6 38.6		Fry et al. **(1946)**
Prickley sculpin		18-19					24.1		Black (1953)
Squawfish		19-22					28.9	24-hr TL50	Black (1953)
Muskellunge	Juvenile	25 27.5 30					32.25 32.75 33.25		Scott (1964)
Golden topminnow	Adult	35					38.5		Strawn and Dunn (1967)
Bayou killifish		35					38.5		Strawn and Dunn (1967)

Appendix M: Part II

Summary of Temperature Tolerances and Preferences for Reservoir Fish*

Species	T_1 Lower Lethal Temperature	Best Temperature Range for Growth T_2	Optimum or Preferred	T_3	T_4 Upper Lethal Temperature
Gizzard shad	10.8 @ 25		16-18?		36.5 @ 35
Threadfin shad	≤1.1 in field				
Northern pike	3.2 @ 17.7 for larvae		26 (larvae)		33.3 @ 30 for juveniles
Grass pickerel			25.5		
Chain pickerel			26.0		≥36.7 in field
Muskellunge			24.0		33.3 @ 30 for juveniles
Carp	0.7		32.0		35.7 @ 26
Goldfish	0 @ 10		28.1		40.5 @ 35 (ultimate)
Golden shiner	1.5 @ 15				34.7 @ 30
Emerald shiner	1.6 @ 15		27		30.7 @ 25 (ultimate)
Common shiner	0 @ 15				32 @ 25-26
Spottail shiner					≥35 in field
Bluntnose minnow	1.0 @ 15				33.3 @ 25
Flathead minnow	1.5 @ 20				33.2 @ 30
Creek chub	0.7 @ 20				32.6 @ 25-26
Duskystripe shiner					32.0 @ 21.5
Longnose sucker					27 @ 11.5
White sucker	2.5 @ 20		27		31.2 @ 25-26
Largescale sucker					29.4 @ 19
Finescale sucker					26.9 @ 14
Brown bullhead	-1.0 @ 20				37.5 @ 36 (ultimate)
Black bullhead					35 @ 23
Channel catfish	0 at 15		30		38.0 @ 35 for yearlings
Banded killifish					≥38.3 in field
Golden topminnow					38.5 @ 35
Mosquitofish	1.5 @ 15				37.3 @ 20-35
Striped bass					32.2
Rock bass					35 @ 30

* All temperatures in ^{o}C.

Appendix M: Part II (Concluded)

Species	T_1 Lower Lethal Temperature	Best Temperature Range for Growth T_2	Optimum or Preferred	T_3	T_4 Upper Lethal Temperature
Longear sunfish	<7 in field				37.5 @ 35 for juveniles
Green sunfish					>34 in field
Redear sunfish	<6.5 in field				
Bluegill	2.5 @ 15		27.7		37.3 @ 32.9 for juveniles
Smallmouth bass	1.6 @ 15		27	28	35
Largemouth bass	5.2 @ 20	25	27	30	37.5 (average)
Pumpkinseed			31.5		24.5 @ 25
Black crappie		22		25	32.5 @ 29
Yellow perch	1.1 @ 10		24.2		30.9 @ 25
Rainbow trout	0		13.3		28
Brown trout		12	15.5	18	25.3 @ 20+ (ultimate)
Kokanee	0 @ 5		14.5		24.8 @ 20 for fry
Coho	0.2 @ 5				25.0 @ 20 for fry
Lake trout		8	12.0	12.0	23.5 @ 15 and 20
Brook trout	0.5 @ 25	10.8	12.8	14.8	26.6
Prickley sculpin					24.1 @ 18 and 19
Northern squawfish					29.3 @ 19-22

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APPENDIX O: BIBLIOGRAPHY

PART I: FISH FOODS

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APPENDIX O: BIBLIOGRAPHY

PART X: FISH CHEMICAL COMPOSITION

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